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Light Weight H.I. Shock Machine Acceleration

Measurements on Typical Auxiliary Mounting Arrangements.

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NAVAL RESEARCH LABORATORY

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NAVY DEPARTMENT

Report on

Light Weight H.I. Shock Machine Acceleration
Measurements on Typical Auxiliary Mounting Arrangements

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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Distribution: BuShips (25)

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INDEX

Subject	Page
INTRODUCTION	1
(a) Authorization	1
(b) Statement of Problem	1
METHODS	1
DATA OBTAINED	1
(a) Acceleration, Velocity, and Displacement Curves	1
(b) Discussion of Curves	2
Table I	4
Table II	5
CONCLUSIONS AND RECOMMENDATIONS	7
References	

APPENDIX

Plates	Number
Mounting Plans and Accelerometer Locations	1, 2, 3
Low Pass Filter Transmission Curves	4 & 5
Effect of Small Shift on Acceleration Zero on Velocity and Displacement	6
Measurements on Typical Mounting Plan, Type "A" Test, Figure 4A	7-12
Measurements on Typical Mounting Plan, Type "A" Test, Figure 4B	13-18
Measurements on Typical Mounting Plan, Type "C" Test, Figure 6C	19-30
Measurements on Typical Mounting Plan, Type "A" Test, Figure 4D	31-42
Measurements on Typical Mounting Plan, Type "C" Test, Figure 6B	43-48

INTRODUCTION

(a) Authorization

1. This work has been authorized by Bureau of Ships project 1438/42. The particular information included has been requested by Bureau of Ships letter S60-(2)(350) of 31 July 1942.

(b) Statement of Problem

2. Measurements of acceleration¹ on different mounting plates used with the light weight HI (High Impact) shock testing machine, have shown the maximum accelerations to be dependent upon the mounting plate used. This report will include the results of acceleration measurements at specified points on available typical mounting plans included in Bureau of Ships Ad Interim Specification² of 1 March 1942.

METHODS

3. Accelerations were measured by means of a quartz crystal accelerometer constructed by Westinghouse. Methods of measurement are similar to those used by Westinghouse³ and General Electric⁴ and will be completely described in a forthcoming report on Shock Measurements⁵ to be issued by the Naval Research Laboratory.

DATA OBTAINED

(a) Acceleration, Velocity, and Displacement Curves

4. Acceleration-time curves have been obtained for mountings shown in Plates 1, 2 and 3, at the locations indicated. These curves have been obtained for 2000 ft-lb. hammer blows and have been obtained for top, side, and back blows against the anvil plate. Records were taken with a 12,000 cycle low pass filter and a 5000 cycle low pass filter (see plates 4 and 5).

5. The complete acceleration-time records have a time axis about 0.1 seconds long. The records given in this report illustrate only a few thousandths of a second at the beginnings of these curves. The included records of accelerations were obtained by tracing a projected enlargement of the original acceleration curves. The velocity and displacement curves were derived from the acceleration curves by a graphical summation of the areas.

6. It is to be emphasized that the errors involved in the integrations of the acceleration curves may be cumulative, therefore, the magnitudes of the probable errors of the velocity and displacement curves increase as the time increases. After 3 or 4 milliseconds this error may have accumulated to such an extent that the velocities and displacements

derived are not sufficiently accurate for use. Values of velocity and displacement during the first few milliseconds are considered of sufficient accuracy (within 20 percent in terms of maximum values).

(b) Discussion of Curves

7. Two equivalent records have been obtained for each condition of measurements. In one record a 5000 cycle low pass filter was used and with the other record a 12,000 cycle low pass filter was employed. The 12,000 cycle records serve to check the 5000 cycle records. A comparison of corresponding records generally show good agreement. The 12,000 cycle records also serve to give a common basis of comparison with previously published values from other sources. The difference between the maximum accelerations obtained with the 5000 cycle and 12,000 cycle low pass filters may be taken as a measure of the amplitudes of frequencies between these two ranges. An apparatus that would measure maximum accelerations for each of many frequency ranges would be most valuable.

8. The locations of the accelerometer positions can be found on the first three plates. Indications are given on the acceleration curves as to which location was used.

9. Velocities and displacements are little affected by frequency components of acceleration above a few thousand cycles per second. From this it can be seen that it is impractical to attempt to obtain high frequency values of acceleration from measured velocity curves.

10. Velocity and displacement curves (derived from the acceleration curves) were initially included to determine whether or not the zero of the accelerometer trace shifted during the shock period. Plate 6 shows what a large effect a small acceleration zero shift has on the velocity and displacement. The anvil plate, to which the mountings are attached, attains its maximum velocity of about 20 ft/sec in about 0.001 second. (The velocity of the anvil plate caused by a back blow is more oscillatory in nature and decreases more rapidly.) Hence the maximum velocities attained by the mountings should be in the order of 20 ft/second. If the mounting is quite flexible this maximum velocity may not be attained. If the mounting acquires resonant vibrations this maximum velocity may be exceeded (see plates 43 and 44).

11. Acceleration curves of the transient states of complicated apparatus are of an exceedingly complex nature. A few curves (Plates 19, 20, 23, 24, 31, 32, 43 and 44) are easily resolvable into persistent frequencies, but generally the curves are non-periodic. All of the acceleration curves, in which the 12,000 cycle low pass filter was used, have recognizable frequencies of about 11,000 cps. It is possible this frequency may be partly characteristic of the accelerometer. It is believed that all frequencies below 10,000 cps are real and that their maximum values are within 10 percent of correct. It would be most satisfactory if acceleration

curves could be described by their frequency components and their maximum values, but in general this is impractical. When such a description is possible it may be well employed. (Note paragraph 13 and the latter part of paragraph 7).

12. Maximum values of acceleration are but one of the many factors necessary for a description of shock. When all factors remain fixed, except the intensity of shock excitation, the maximum value may be a good indication of comparative shock. Table 1 lists the maximum accelerations for the various mountings studied. These values, in many cases, occur after time intervals later than shown on the included plates. The mounting positions are shown on the first three plates.

13. Table 2 illustrates an attempt to obtain more numerical information from the acceleration curves. In this table the greatest average accelerations, for definite time intervals, that occur in the acceleration-time curve are tabulated. From these data maximum impulses can be obtained. For impulses of longer time interval than a few thousandths of a second the crystal accelerometer will not as yet give reliable results. Numerical information of this kind together with information on definite acceleration frequencies and their magnitude may be considered a sufficient description of shock as determined by acceleration measurements. It is expected that the table may be completed for long time intervals by displacement measurements. It is hoped that these displacements, together with information on distortion, may be obtained by means of high speed photography.

14. As is shown on plate 43 the greatest average value of acceleration, for a given time, can be obtained either directly from the acceleration curve or from the slope of the velocity curves. For complex acceleration curves it is usually easier to work through the velocity record.

15. Where much of the shock is caused by the high frequency (above 5000 cps) accelerations there is less probability of good accuracy in the velocity and displacement curves. If this high frequency is removed by filtering, the part contributed by these components will be lost. (see plates 15, 16, 39, 40). In most cases the contributions of acceleration frequencies above 5000 cps to the velocities are negligible.

16. If the velocities have attained their maximum values in about 0.002 seconds, and they have for most of the cases considered, then the maximum average accelerations for longer periods of time must be less than the average acceleration for 0.002 seconds time the ratio of 0.002 seconds to the longer time considered. Thus for plate 7 (see first row of table 2) the average acceleration for a time of 0.02 seconds can not be greater than

$$\frac{0.002}{0.02} \times 300g = 30g$$

although it may have any value up to the above.

17. Plates 31, 32, 35, 36, 43 and 44 call for special comment because of their high magnitude resonant vibrations. The circuit breaker mounting develops an oscillation of about 2500g amplitude at 560 cycles/sec. This brings the average accelerations, for the longer time intervals considered, to values many times greater than corresponding values for other mountings.

TABLE I

MAXIMUM ACCELERATIONS FOR HAMMER ENERGY OF 2000 FT-LBS.

Mounting (figure)	Location on Mounting	Maximum Acceleration with Low Pass Filter of	
		5000 cps	12,000 cps
BACK BLOW			
4A	Central	-1600g	+2450g
4B	Central	-1850g	-3250g
6B	Central on Bar	+2450g	+3100g
6C	Central	+ 800g	+1050g
	Lower Channel	+1300g	+1700g
4D	On Pipe	+1350g	-2400g
	Top Plate	-1400g	+1500g
Average of absolute values		1536g	2207g
END BLOW			
4A	Central	+ 650g	+1100g
4B	Central	-1500g	+1350g
6B	Center of Bar	+ 950g	+1150g
6C	Central	+ 600g	+ 800g
	Lower Channel	+ 550g	+ 700g
4D	On Pipe	+1050g	-1200g
	Top Plate	+ 800g	+1150g
Average of absolute values		871g	1064g
TOP BLOW			
4A	Central	- 900g	-1250g
4B	Central	-1250g	-1875g
6B	Center of Bar	+ 450g	+ 650g
6C	Central	+ 600g	- 750g
	Lower Channel	- 700g	-1100g
4D	On Pipe	+ 950g	-1400g
	Top Plate	- 850g	+1700g
Average of absolute values		807g	1246g

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TABLE II

GREATEST AVERAGE ACCELERATIONS THAT OCCUR IN THE ACCELERATION CURVES
FOR VARIOUS INTERVALS OF TIME*

Plate # and description	Maximum acceleration	<u>(2000 ft-lb hammer energy)</u> Greatest average acceleration over a period of: (seconds)				Remarks
		.00025	.0005	.001	.002	
<u>34" x 26" x 1/2" Plate (4A)</u>						
7B 5**	1600g	1200g	930g	590g	300g	
8B12	2400	1240	870	420	200	
9T 5	900	500	370	280	225	
10T12	1250	750	500	260	220	
11E 5	650	500	420	230	200	
12E12	1100	750	590	340	290	
<u>15" x 26" x 1/2" Plate (4B)</u>						
13B 5	1850	1200	1200	900	530	
14B12	3250	1240	780	640	460	- - - strong 10,000cps
15T 5	1250	870	400	220	100	- - - zero shift
16T12	1875	960	400	220	100	- - - zero shift
17E 5	1500	1430	1150	700	310	
18E12	1350	900	800	560	310	
<u>Plate (6C) Central</u>						
19B 5	600	570	570	560	390	strong 150 cps
20B12	800	700	680	600	370	vibration for
21T 5	800	550	440	260	170	most blows on
22T12	1050	440	380	310	220	this plate
23E 5	600	370	310	250	250	
24E12	800	610	580	310	300	
<u>Plate (6C) Lower Channel</u>						
25B 5	1300	680	600	520	380	
26B12	1700	810	700	520	400	
27T 5	700	640	550	350	250	
28T12	1100	750	530	300	220	
29E 5	550	450	340	300	250	
30E12	700	570	470	280	160	

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Table II continued

Plate # and description	Maximum acceleration	<u>(2000 ft-lb hammer energy)</u> Greatest average acceleration over a period of: (seconds)				Remarks
		.0025	.0005	.001	.002	
<u>Searchlight Mounting (4D) Position on Pipe</u>						
31B 5	1350	1120	900	590		strong 800 cycle vibr.
32B12	2400	1000	900	650		
33T 5	950	560	430	310	230	
34T12	1400	670	500	310	190	
35E 5	1050	1000	960	560		strong 670 cycle vibr.
36E12	1200	1050	930	500		
<u>Searchlight Mounting (4D) Position on Plate</u>						
37B 5	1400	870	750	500	250	
38B12	1500	780	750	500	280	
39T 5	850	450	310	220	160	
40T12	1700	810	440	250	220	10000 cps
41E 5	800	560	470	410	160	
42E12	1150	500	380	320	120	
<u>Circuit Breaker Mounting (6B)</u>						
43B 5	2450	2400	2200	1600		strong 560 cycle vibr.
44B12	3100	2700	2400	1600		
45T 5	450	300	250	250	250	
46T12	650	460	460	290	250	
47E 5	950	820	620	530	400	
48E12	1150	860	700	580	400	

* If there are oscillations in the derived velocity curve that are of short duration compared with the time interval considered then a smooth curve should be taken along the axis of the local oscillations. The greatest average acceleration should be taken with respect to the smooth curve. When there are large local oscillations that have a period about equal to the time interval considered, no value of the maximum average acceleration should be taken for that interval. (see plate 43).

** The first number of this description refers to the plate number. The letter refers to whether the blow was back, top, or end. The last number refers to the 5000 or the 12,000 cycle low pass filter in use.

CONCLUSIONS AND RECOMMENDATIONS

18. The following conclusions and recommendations are suggested:

(a) Each mounting method results in a different acceleration curve both in regard to general shape and maximum value. Additional weights attached to the mounts will cause still different characteristics. Therefore for specifications it is suggested that mounting plans be completely described for each type of apparatus tested.

(b) The different H.I. shock machines should be standardized. This may be done by measuring the accelerations at given points on the anvil (striking) plate to provide a comparison between machines. This has been done by Westinghouse and General Electric for machines in their use. It is preferable that the measurements be done with one set of measuring apparatus. A machine may be considered standardized when its maximum accelerations agree within specified limits to those obtained by an average of other machines in good condition, and when there are no other marked differences in their acceleration curves.

(c) With shock machines standardized, and with mounting plans specified, the measurements of accelerations for routine acceptance tests should not be necessary. It may be advisable to measure accelerations on the mounting plates at the time of standardization.

(d) When information valuable for design improvements of apparatus under test is desired, all possible measurements indicative of shock severity should be made. These involve mainly acceleration measurements and analysis of high speed moving picture records.

(e) From Table 1 and a study of the curves it is concluded that the maximum acceleration is about twice as great for the back blow as for blows in the other directions.

(f) The magnitude of accelerations having frequency components above 5000 cps is least for the end blow. These frequencies have little effect on the velocities and displacements.

(g) In general the acceleration records, for frequencies above about 500 cycles/second, are nonperiodic. It does not appear practical to attempt to describe the acceleration curves by giving their frequency components together with their magnitudes. Equivalent description may be had by giving maximum average accelerations for definite short time intervals. When periodic vibrations occur their frequencies and magnitudes should be indicated.

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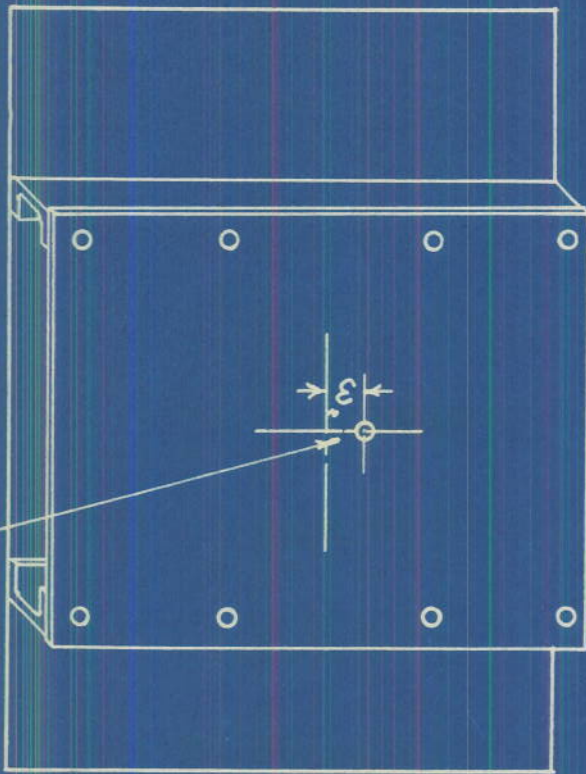
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Maximum Accelerations of $\frac{1}{2}$ " Plate
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D.R. Miller, General Engineering Laboratory
General Electric Company, Schenectady
2. Bureau of Ships Ad Interim
Specification 17E13 (Int) 1 March 1942
3. Shock Testing - Instrumentation for Measuring Shock
General Electric Data Folder #71615
D.H. Marquis 18 April 1942
4. Shock Testing - Instrumentation for Measuring Shock
Westinghouse Research Memo SM-122
F.C. Rushing and R.L. Wells 10 March 1942
5. High Intensity Shock Measurements
Report to be issued by the Naval Research Laboratory

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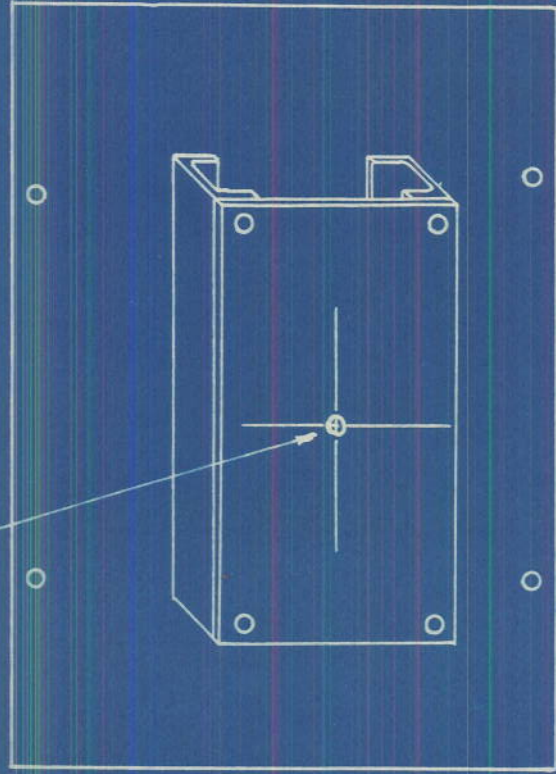
Accelerometer Mounting



34" x 26" $\frac{1}{2}$ " Auxiliary Mounting Plate

Type "A" Test
(Fig 4A)

Accelerometer Mounting (Centered)

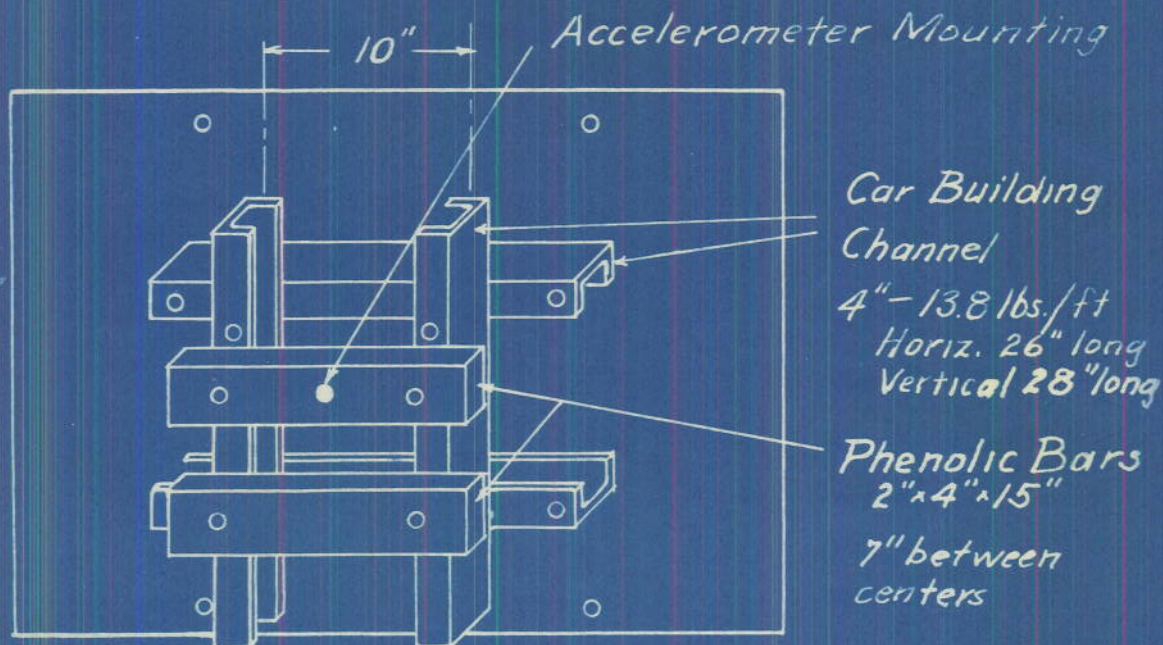


15" x 26" $\frac{1}{2}$ " Auxiliary Mounting Plate

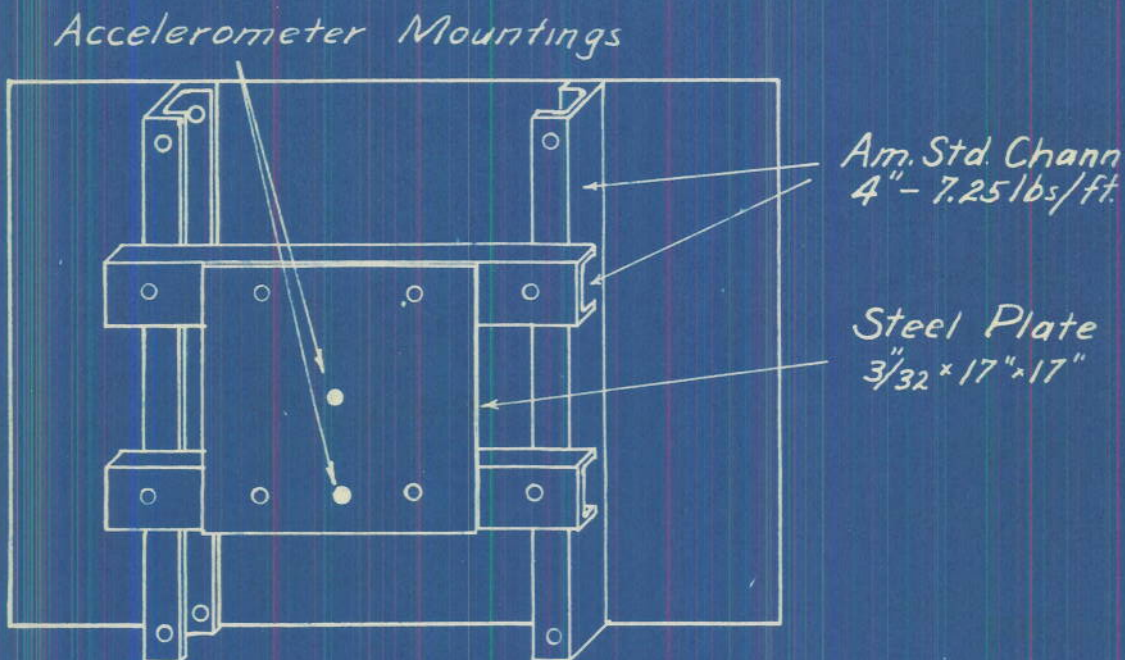
Type "A" Test
(Fig 4B)

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Type "C" Test
(Fig 6B)

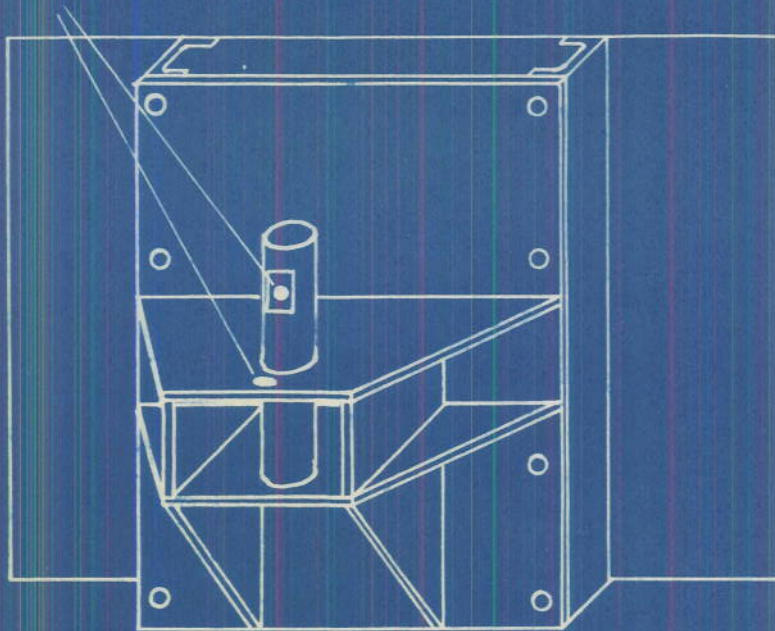


Type "C" Test
(Fig 6C)

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Accelerometer Mountings



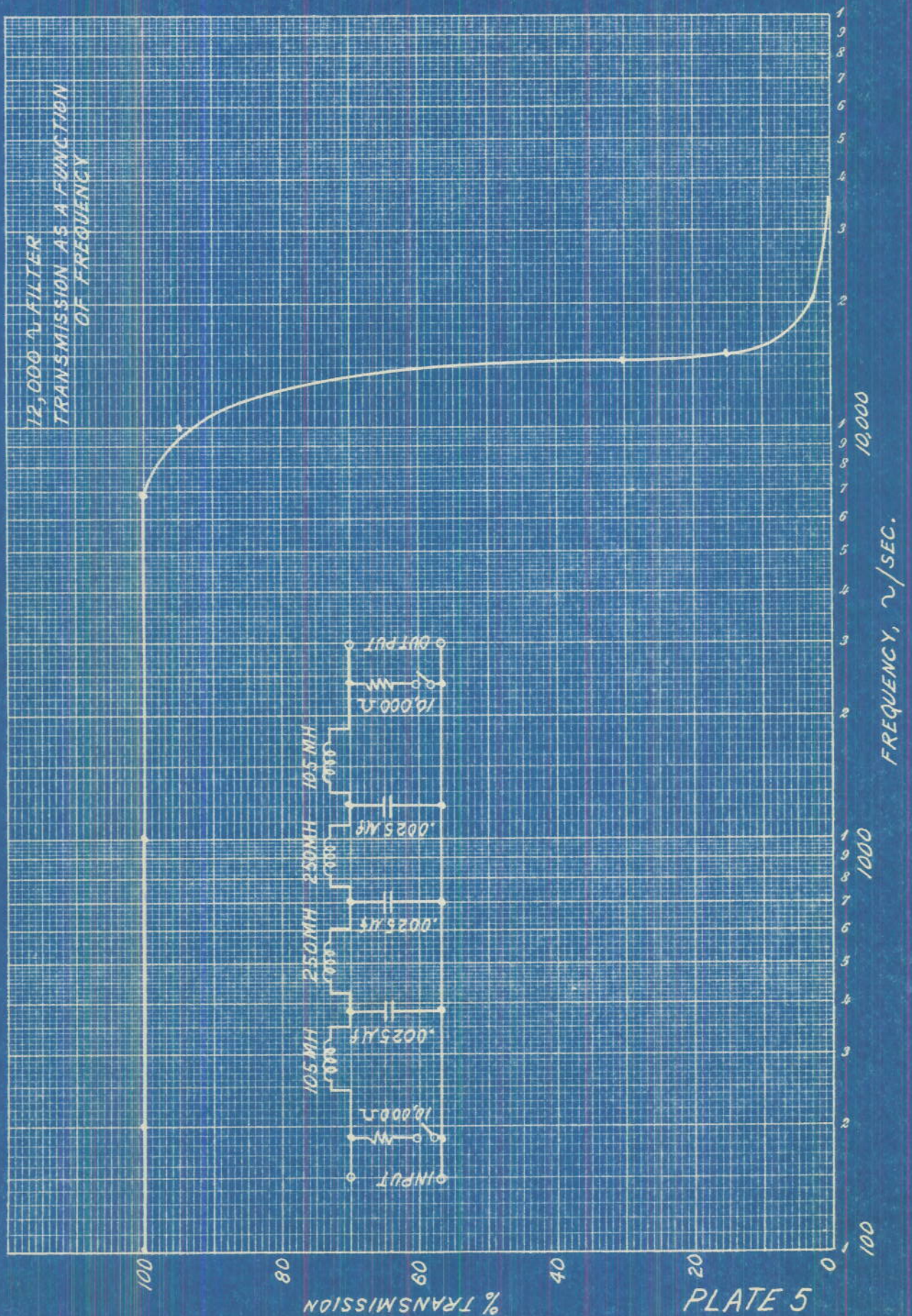
*Type "A" Test
(Fig 4D)*

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CODING BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS



NO. 3115, 20 DIVISIONS PER INCH (120 DIVISIONS) BY 3 1/2-INCH CYCLES RATIO RULE.





EFFECT OF A SMALL ACCELERATION ZERO
DISPLACEMENT ON VELOCITY & DISPLACEMENT.
THE SCALES USED ARE SIMILAR TO THOSE USED IN
THE FOLLOWING GRAPHS

ACCELERATION

2000 G

0

VELOCITY

20 FT/SEC

0

DISPLACEMENT

10 IN

0

0

001

002

003

004

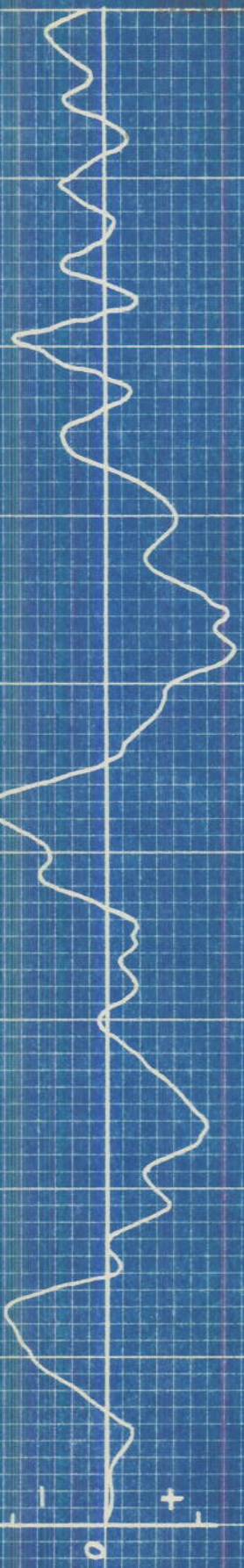
SECONDS

THE ABOVE SMALL ZERO SHIFT OF ACCELERATION
PRODUCES CHANGES OF VELOCITY, AFTER A FEW
MILLISECONDS, OF THE ORDER OF MAGNITUDE OF
THAT PRODUCED BY THE ORDINARY ACCELERATION
CURVES. THIS ILLUSTRATES THAT THE VALUES OF
VELOCITY AFTER THE FIRST FEW MILLISECONDS
ARE NOT ACCURATE.

Back Blow, 2000 ft-lb.
34" x 26" x 1/2" Plate (4A)
5000 n Filter (Low Pass)
9-18-42

-200g Acceleration

■ = 0.293 ft/sec. velocity

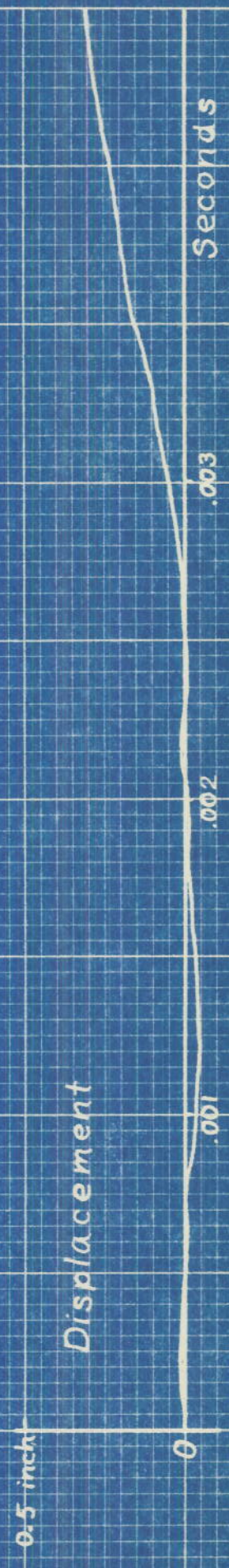


Velocity

■ = 0.0012 inches displacement



Displacement



NO. 571250, 10 DIVISIONS PER INCH DATA MARKS, 10 X 100 MILLIMETERS

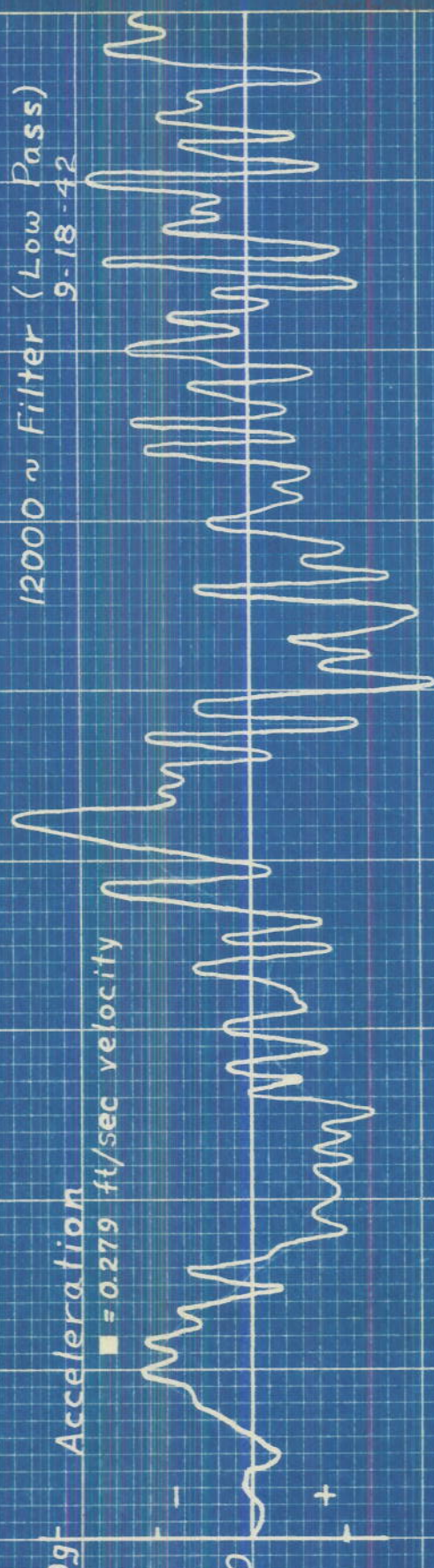


Back Blow, 2000 ft-lbs
34" x 26" x 1/2" Plate (4A)
12000 ~ Filter (Low Pass)
9-18-42

Acceleration

■ = 0.279 ft/sec velocity

-2000g



Velocity

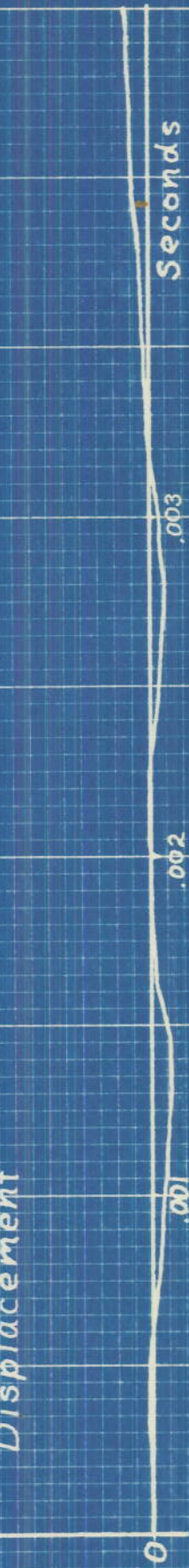
■ = 0.0012 inches displacement

10 ft/sec



Displacement

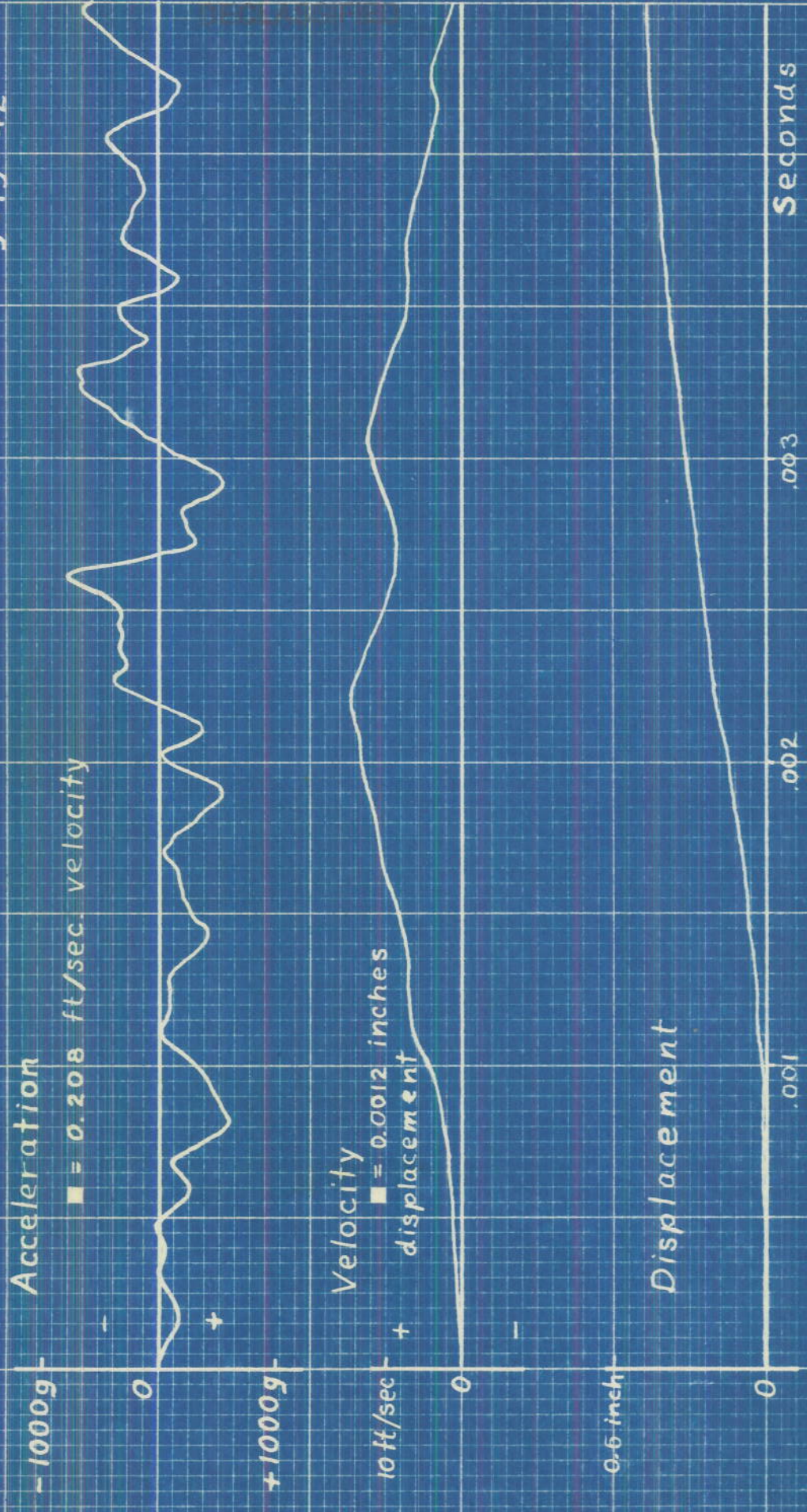
0.5 inch



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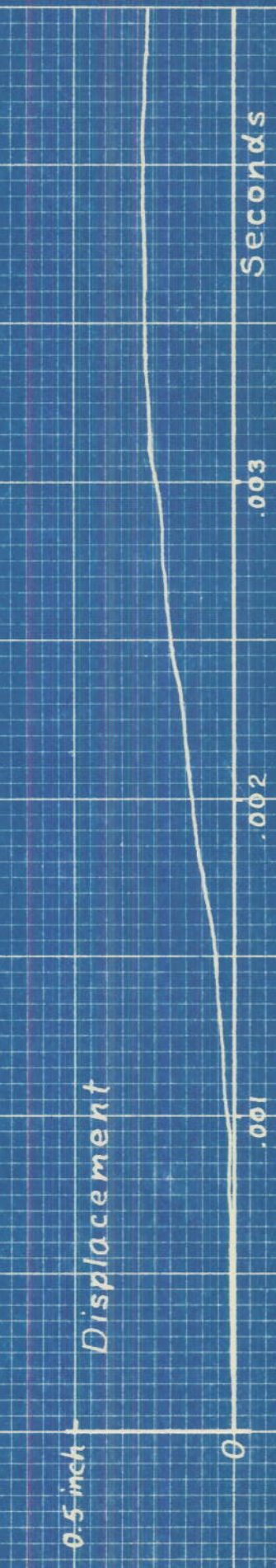
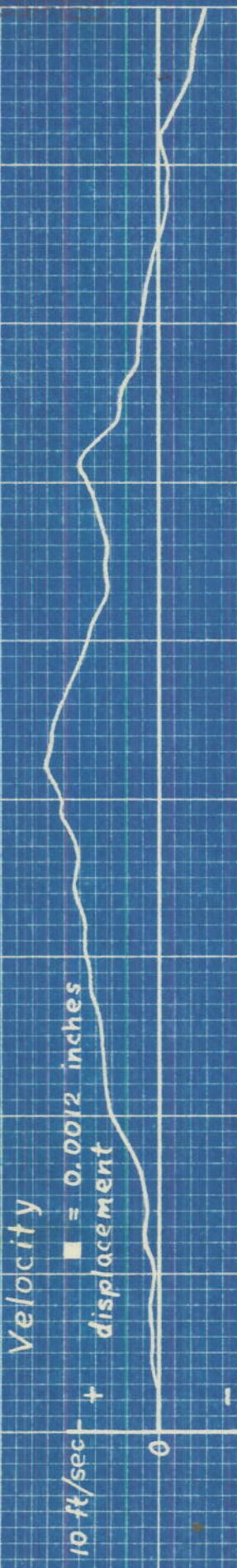
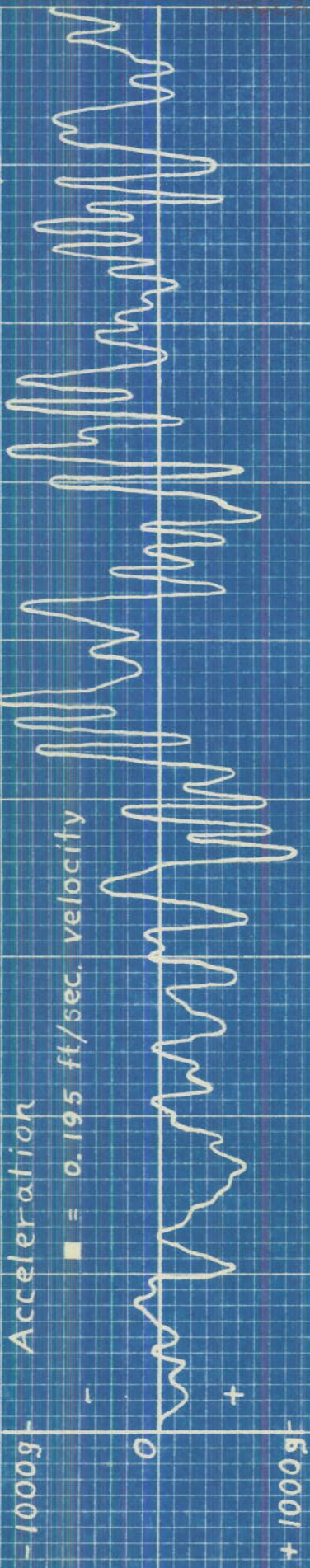
Plate 8

Top Blow, 2000 ft-lbs.
34" x 26" x 1/2" Plate (4A)
5000 ~ Filter (Low Pass)
9-19-42





Top Blow, 2000 ft-lbs.
34" x 26" x 1/2" Plate (4A)
12000 ~ Filter (Low Pass)
9-19-42



NO. 31,190. 10 DIVISIONS PER INCH BOTH VERTICALS. 70 X 100 DIVISIONS.



End Blow, 2000 ft-lbs
34" x 26" x 1/2" Plate (4A)
5000 ~ Filter (Low Pass)
9-16-42

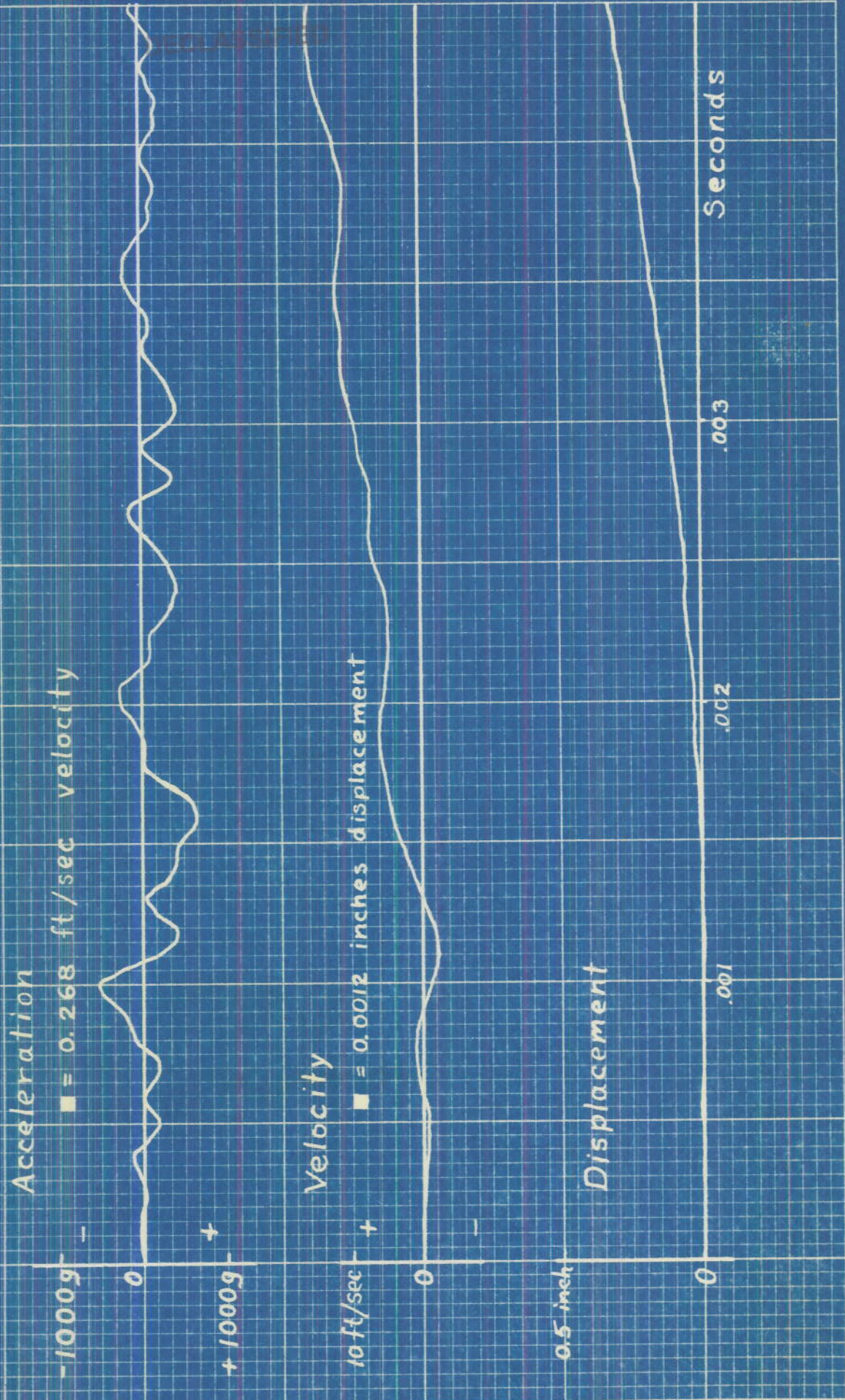
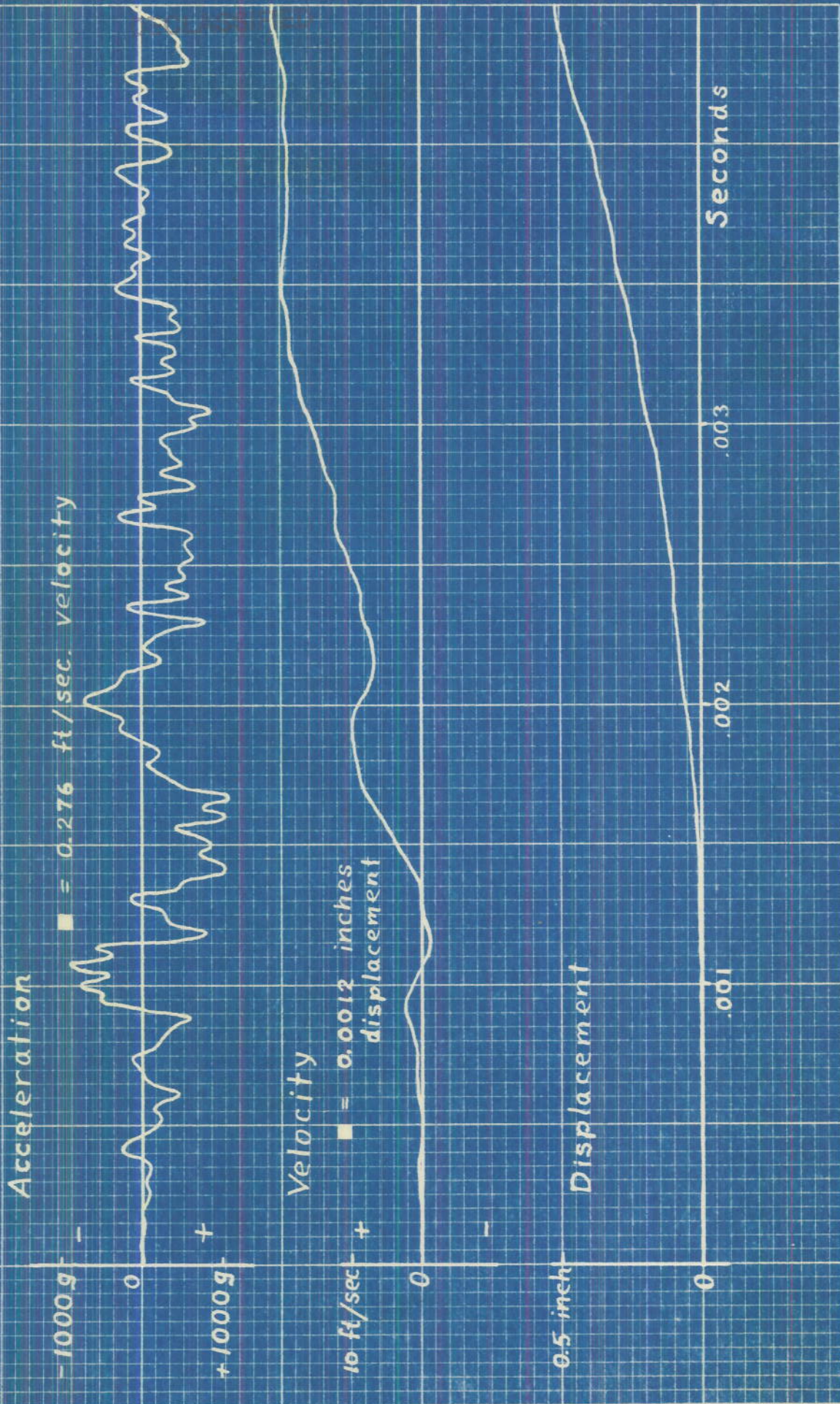


Plate 11

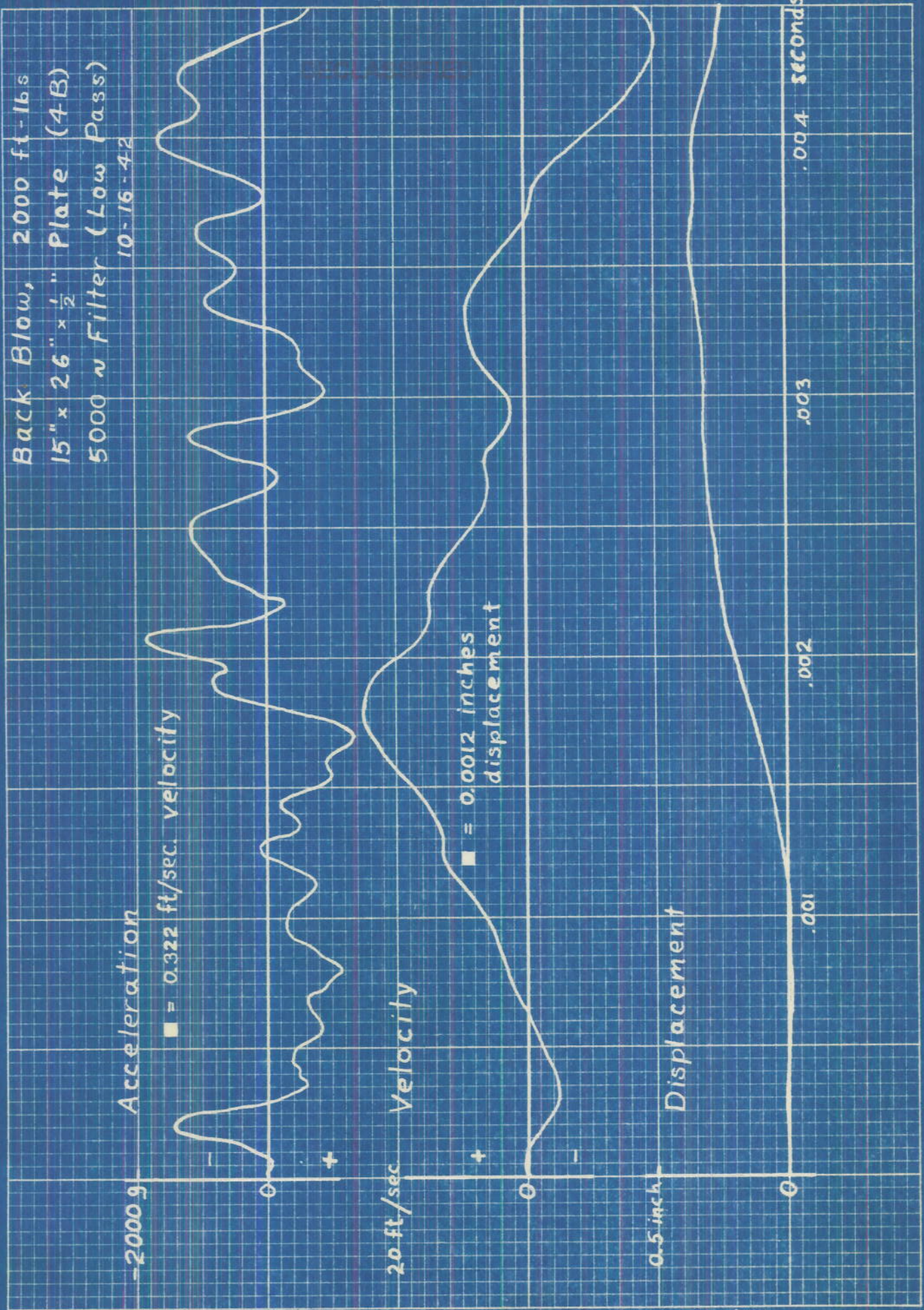
DECLASSIFIED

End Blow, 2000 ft-lbs.
34" x 26" x 1/2" Plate (4A)
12000 ~ Filter (Low Pass)
9-16-42



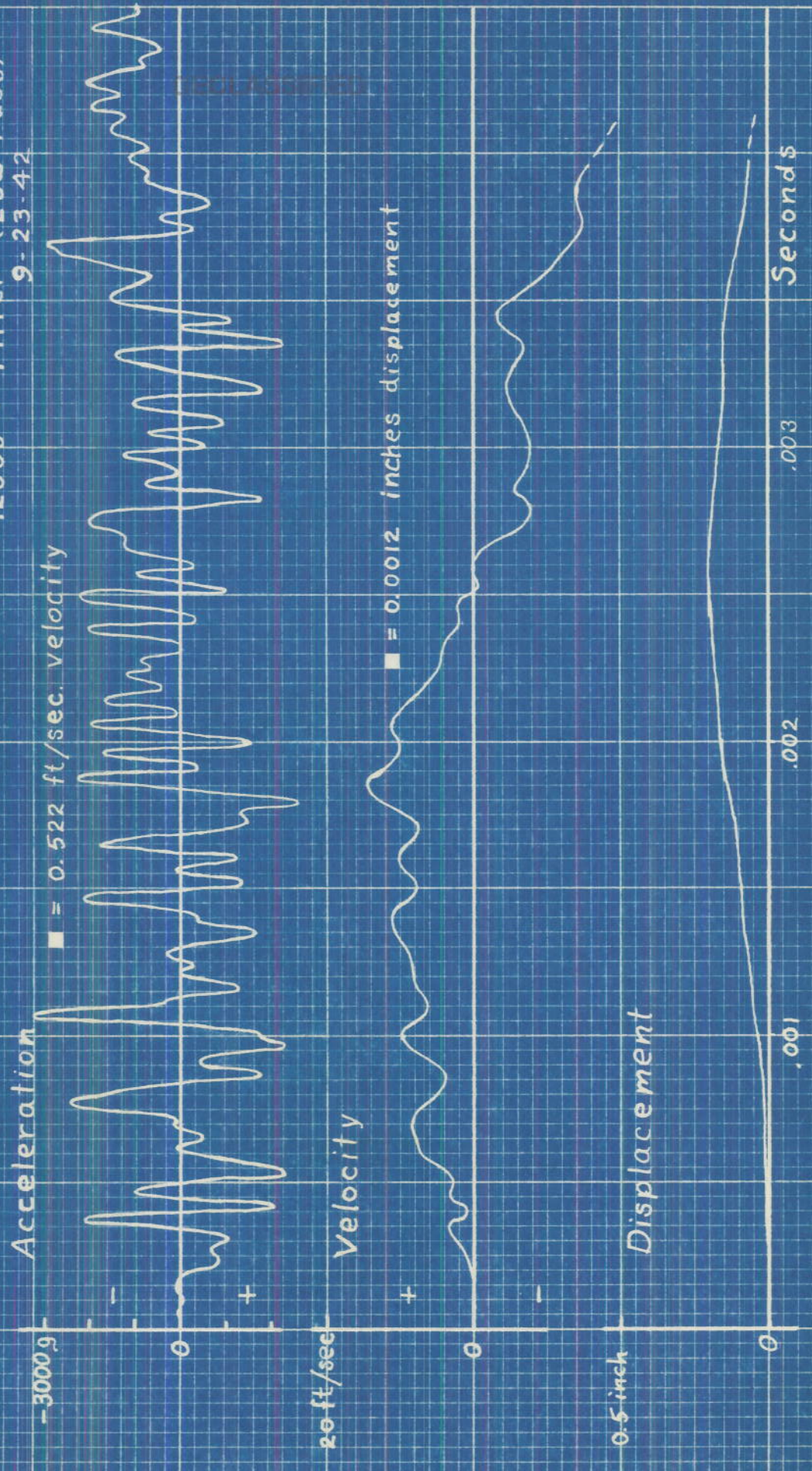


Back Blow, 2000 ft-lb s
15" x 26" x 1/2" Plate (4B)
5000 ~ Filter (Low Pass)
10-16-42



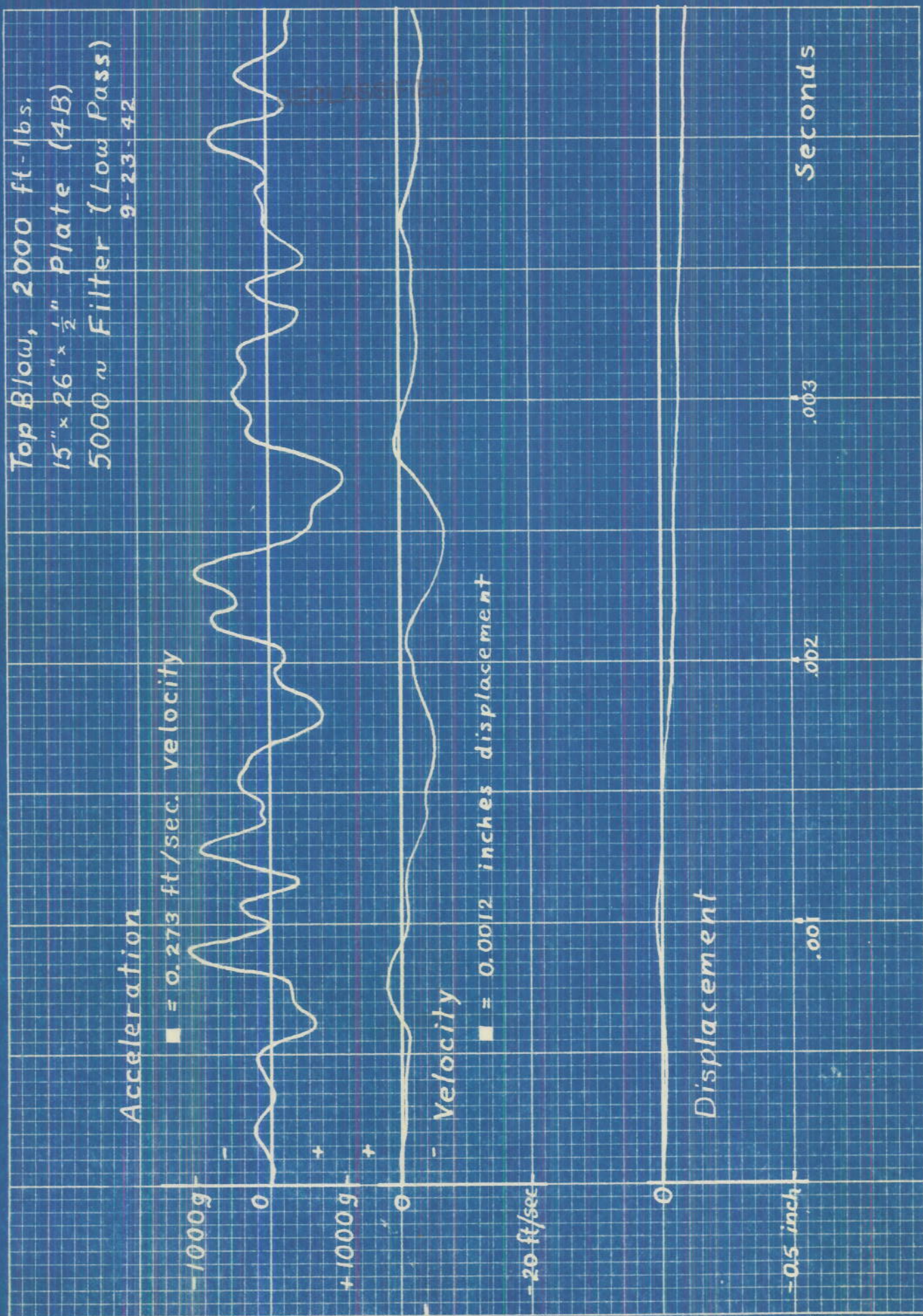


Back Blow, 2000 ft-lbs
15" x 26" x 1/2" Plate (4B)
12000 ~ Filter (Low Pass)
9-23-42





Top Blow, 2000 ft-lbs.
15" x 26" x 1/2" Plate (4B)
5000 ~ Filter (Low Pass)
9-23-42



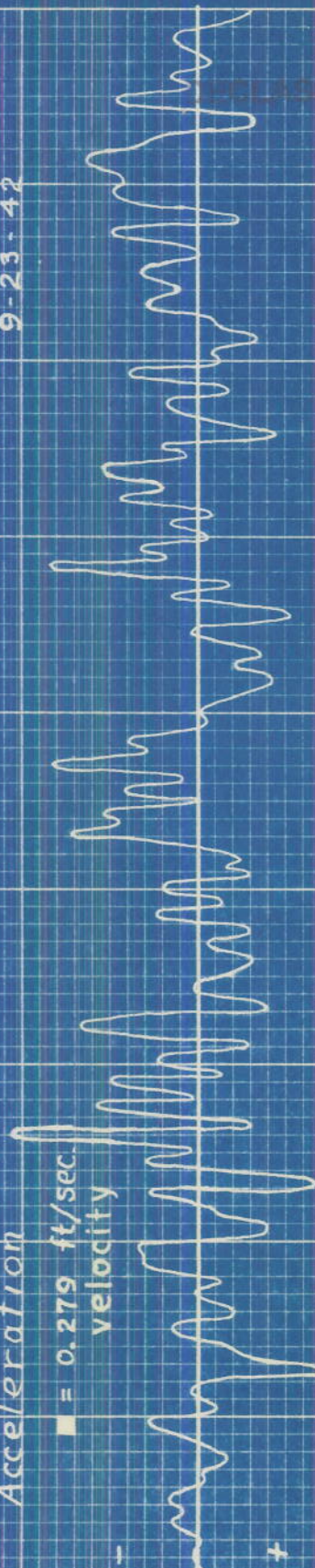


Top Blow, 2000 ft-lbs.
15" x 26" x 1/2" Plate (4B)
12000 ~ Filter (Low Pass)

Acceleration

■ = 0.279 ft/sec.
velocity

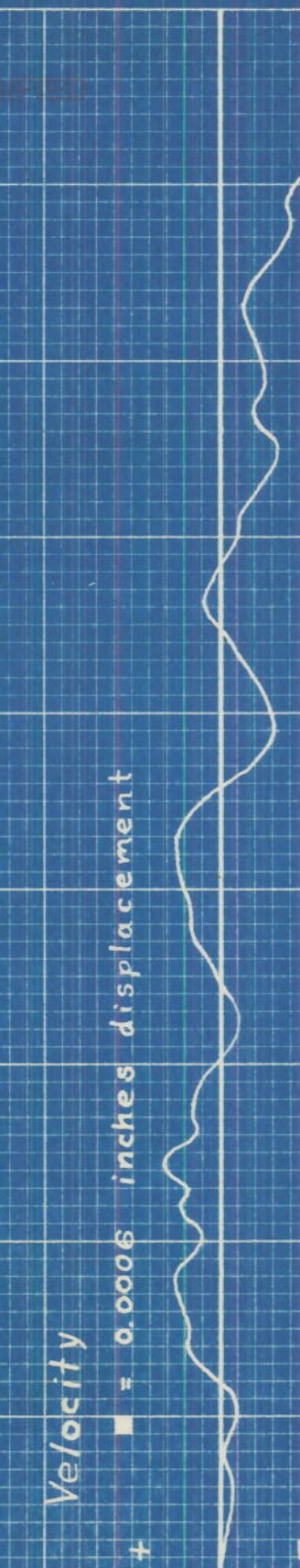
-1000 g



Velocity

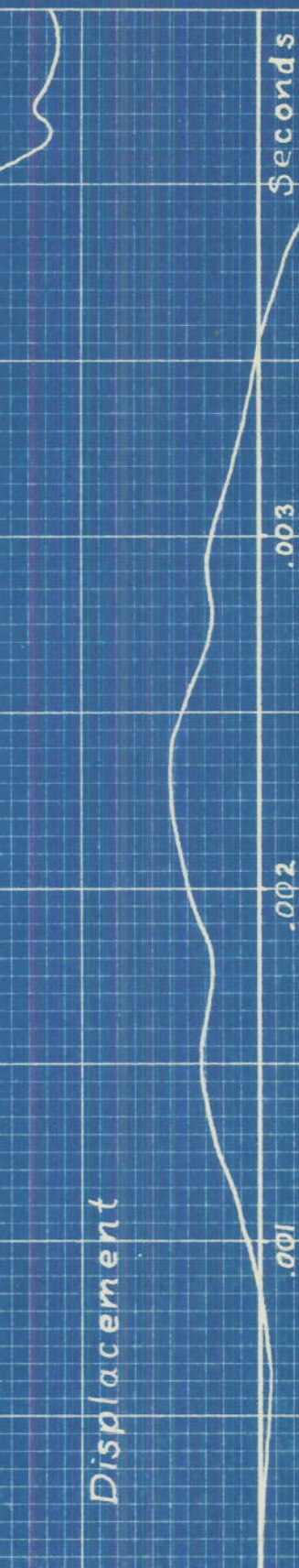
■ = 0.0006 inches displacement

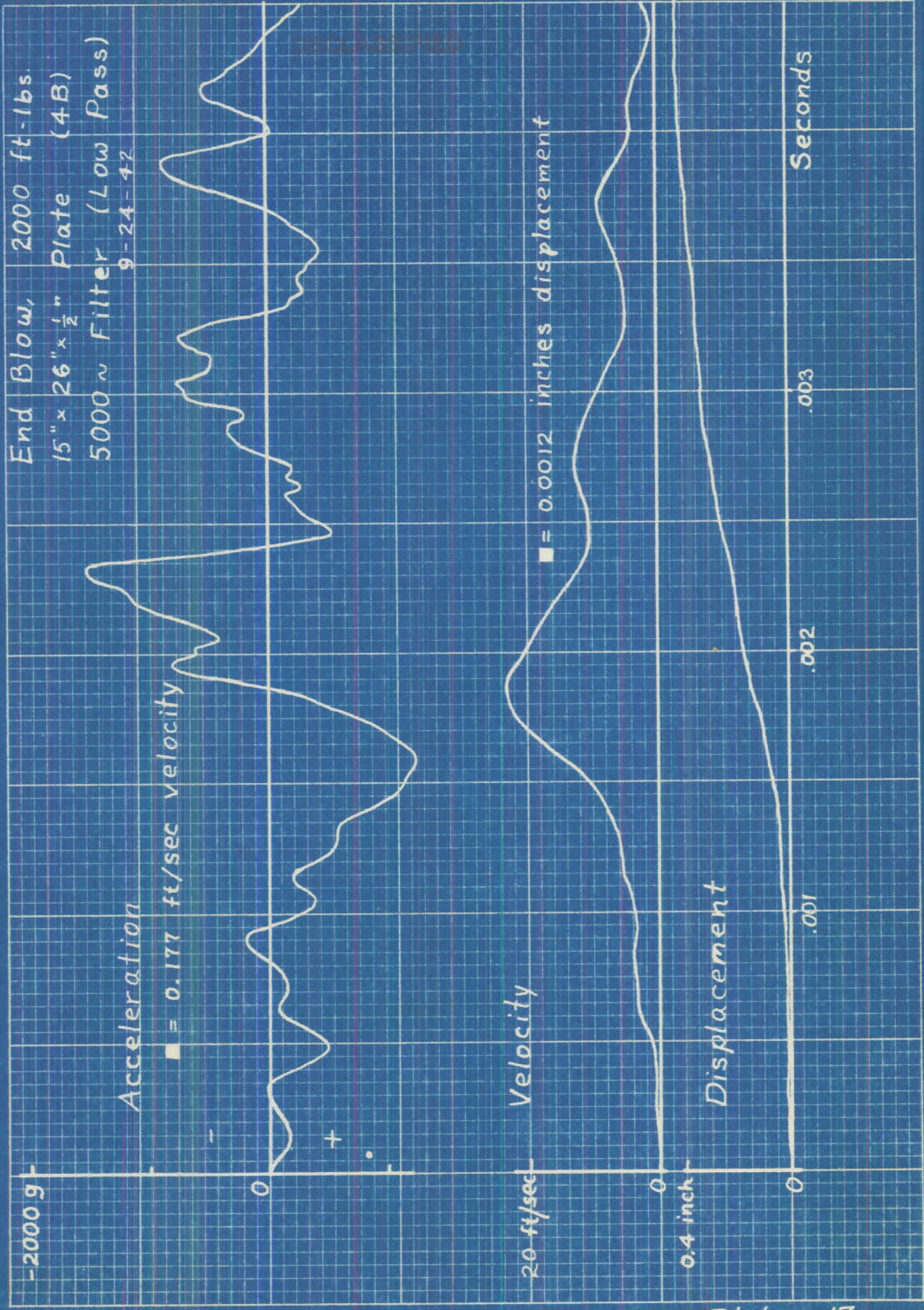
10 ft/sec



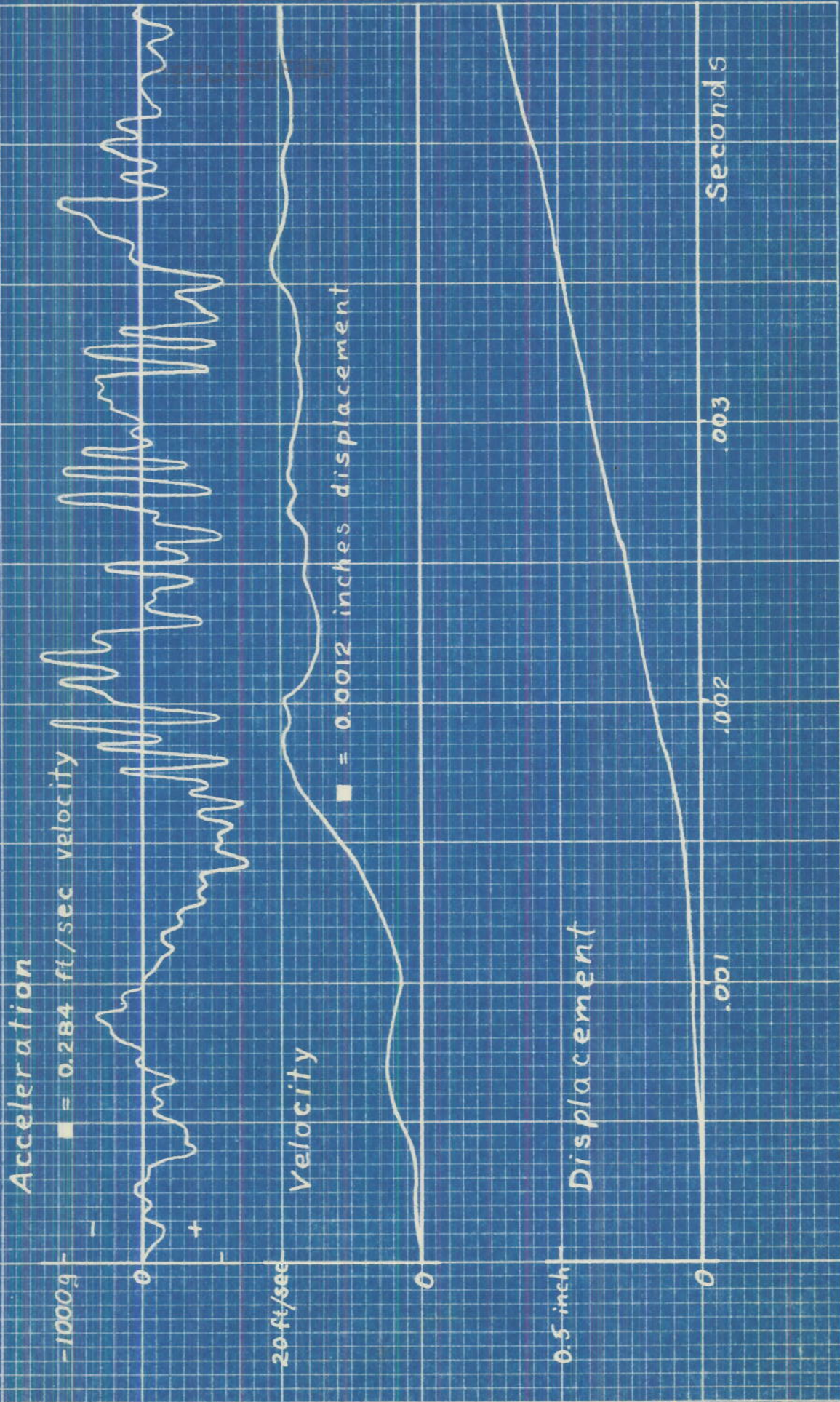
Displacement

.05 inch





End Blow, 2000 ft-lbs.
15" x 26" x 1/2" Plate (4B)
12000 ~ Filter (Low Pass)
9-24-42





Back Blow, 2000 ft.-lbs.
 17" x 17" x $\frac{3}{32}$ " Plate (6C)
 Position - Center of plate
 5000 ~ Filter (Low Pass)
 9-29-42

Acceleration
 ■ = 0.560 ft/sec. velocity

Velocity

■ = 0.0024 inches displacement

Displacement



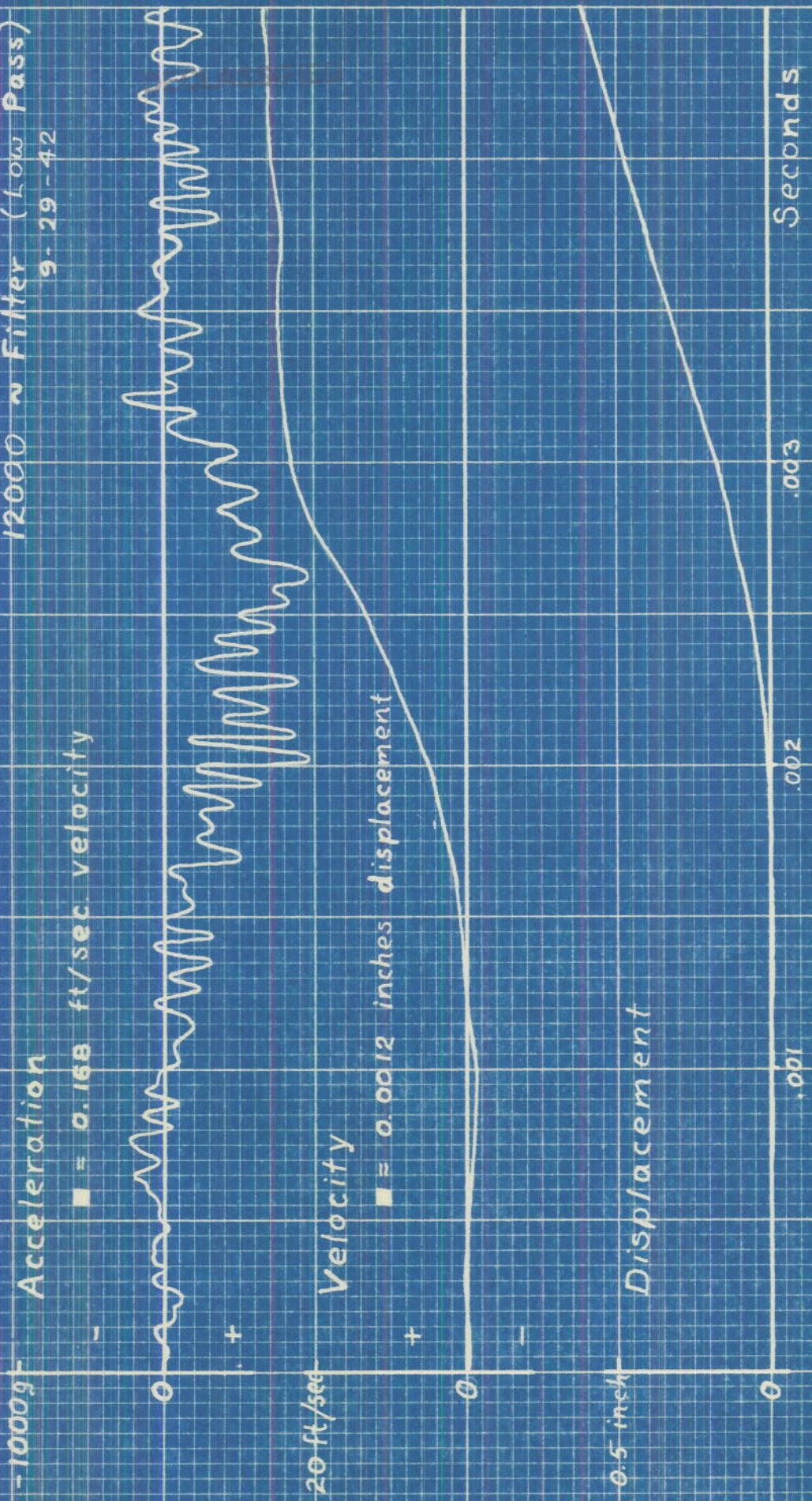
Seconds

(Note time scale not standard)

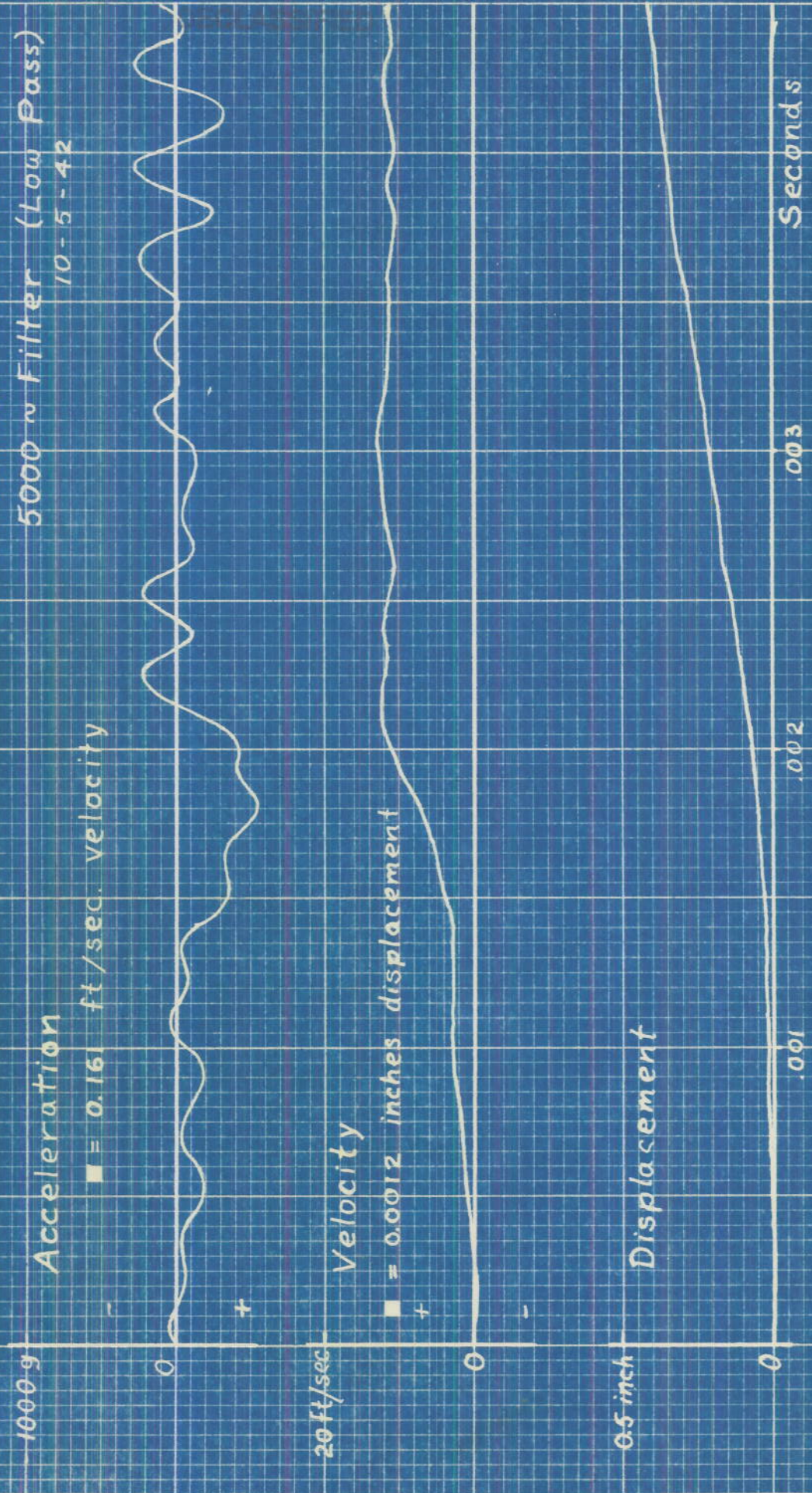
Back Blow, 2000 ft-lbs
 17" x 17" x $\frac{3}{32}$ " Plate (6C)
 Position - Center of Plate
 12000 ~ Filter (Low Pass)
 9-29-42

Acceleration
 = 0.168 ft/sec. velocity

Velocity
 = 0.0012 inches displacement



Top Blow, 2000 ft-lbs.
 17" x 17" x $\frac{3}{32}$ " Plate (6C)
 Position - Center of Plate
 5000 ~ Filter (Low Pass)
 10-5-42



NO. 31,150. 10 DIVISIONS PER INCH DATA WAYS. 10 X 100 DIVISIONS.



Top Blow, 2000 ft.-lbs.
17" x 17" x 3/4" Plate (6C)
Position - Center of Plate
12000 ~ Filter (Low Pass)
10-5-42

-1000g
+
Acceleration

■ = 0.259 ft/sec velocity

20 ft/sec
+
Velocity

■ = 0.0016 inches displacement

0.5 inch
+
Displacement

Seconds

(Scale not std.)

NO. 31, 150. 10 DIVISIONS PER INCH BOTH VERTICALS. 70 X 100 DIVISIONS. COVER BOOK COMPANY, INC.



End Blow, 2000 ft-lbs.
17" x 17" x $\frac{3}{32}$ " Plate (6C)
Position - Center of Plate
5000 ~ Filter (Low Pass)
9-28-42

-1000g
Acceleration

■ = 0.173 ft/sec. velocity



20 ft/sec

Velocity

■ = 0.0012 inches displacement

0

0.5 inch

Displacement

.001

.002

.003

Seconds

End Blow, 2000 ft-lbs.
 17" x 17" x $\frac{3}{32}$ " Plate (6C)
 Position - Center of Plate
 12000 n Filter (Low Pass)
 9-28-42

(Note + accel.
 is upward)

Acceleration

■ = 0.161 ft/sec. velocity

Velocity

■ = 0.0012 inches displacement

Displacement

+ 1000 g

20 ft./sec

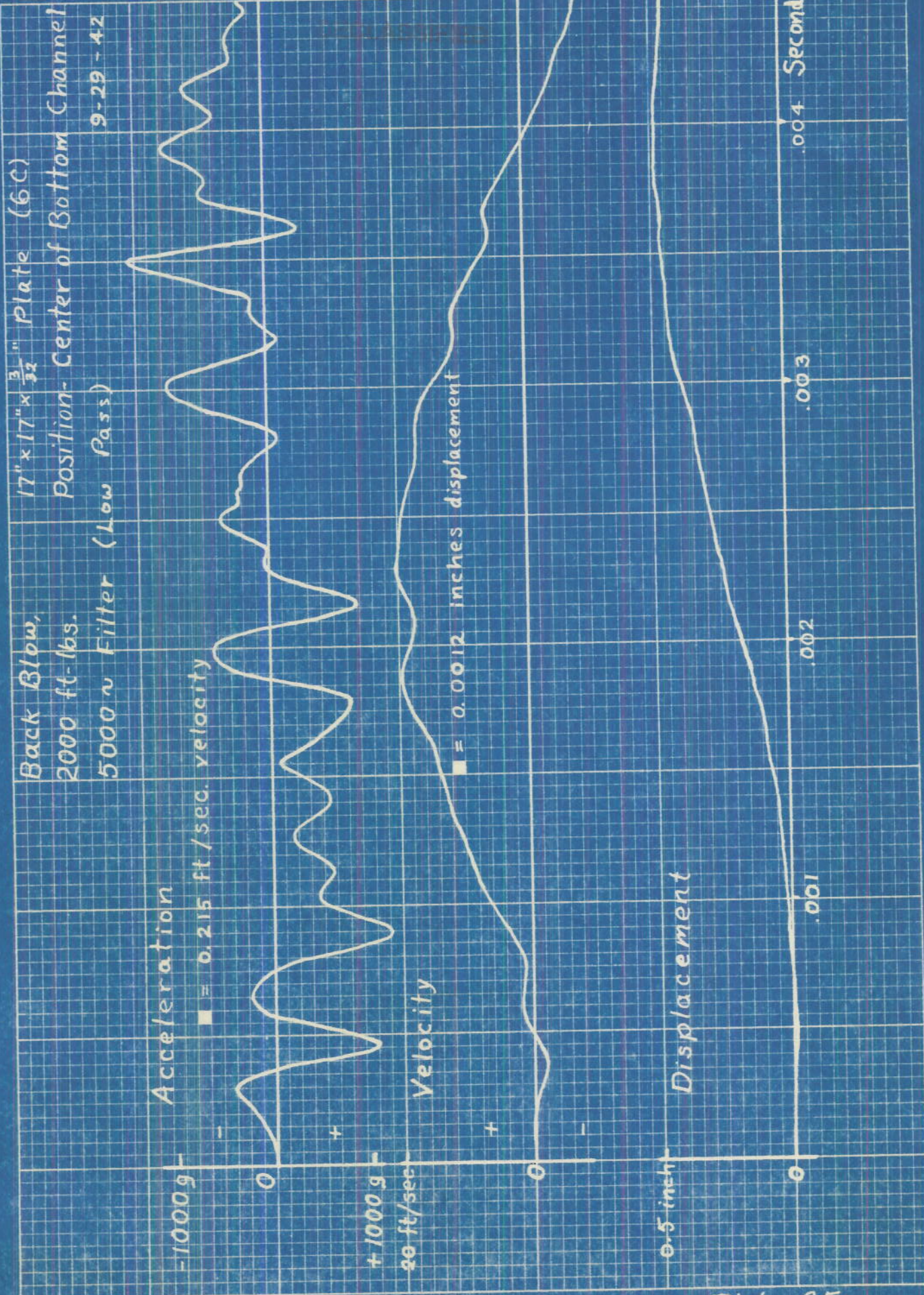
0.5 inch

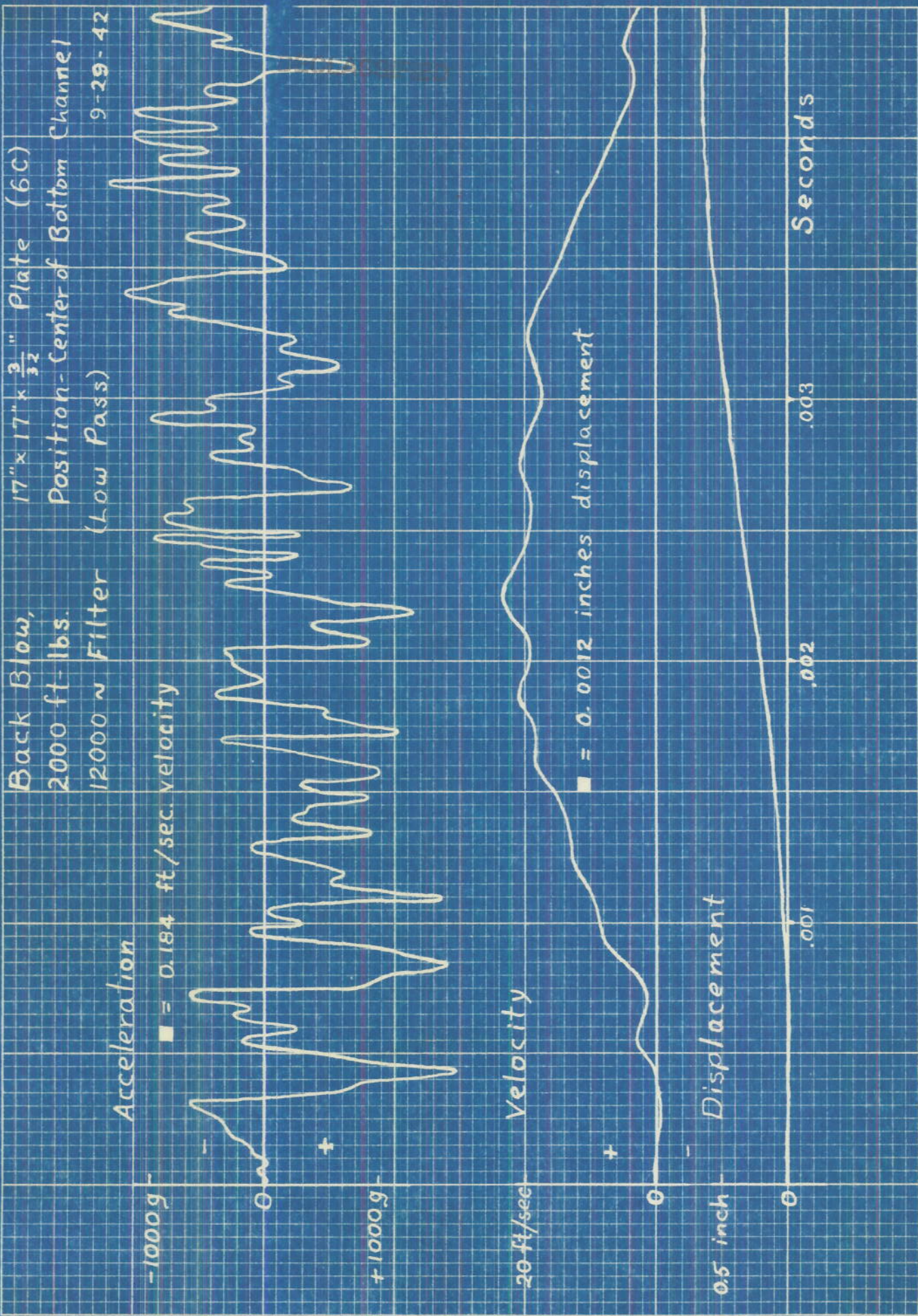
.001

.002

.003

.004 Seconds





Top Blow
2000 ft-lbs.
5000 n Filter (Low Pass)

17" x 17" x $\frac{3}{32}$ " Plate (6C)

Position - Center of Bottom Channel

10-5-42

-1000g

Acceleration

■ = 0.131 ft/sec. velocity

0

20 ft/sec

Velocity

0

■ = 0.0012 inches displacement

0.5 inch

Displacement

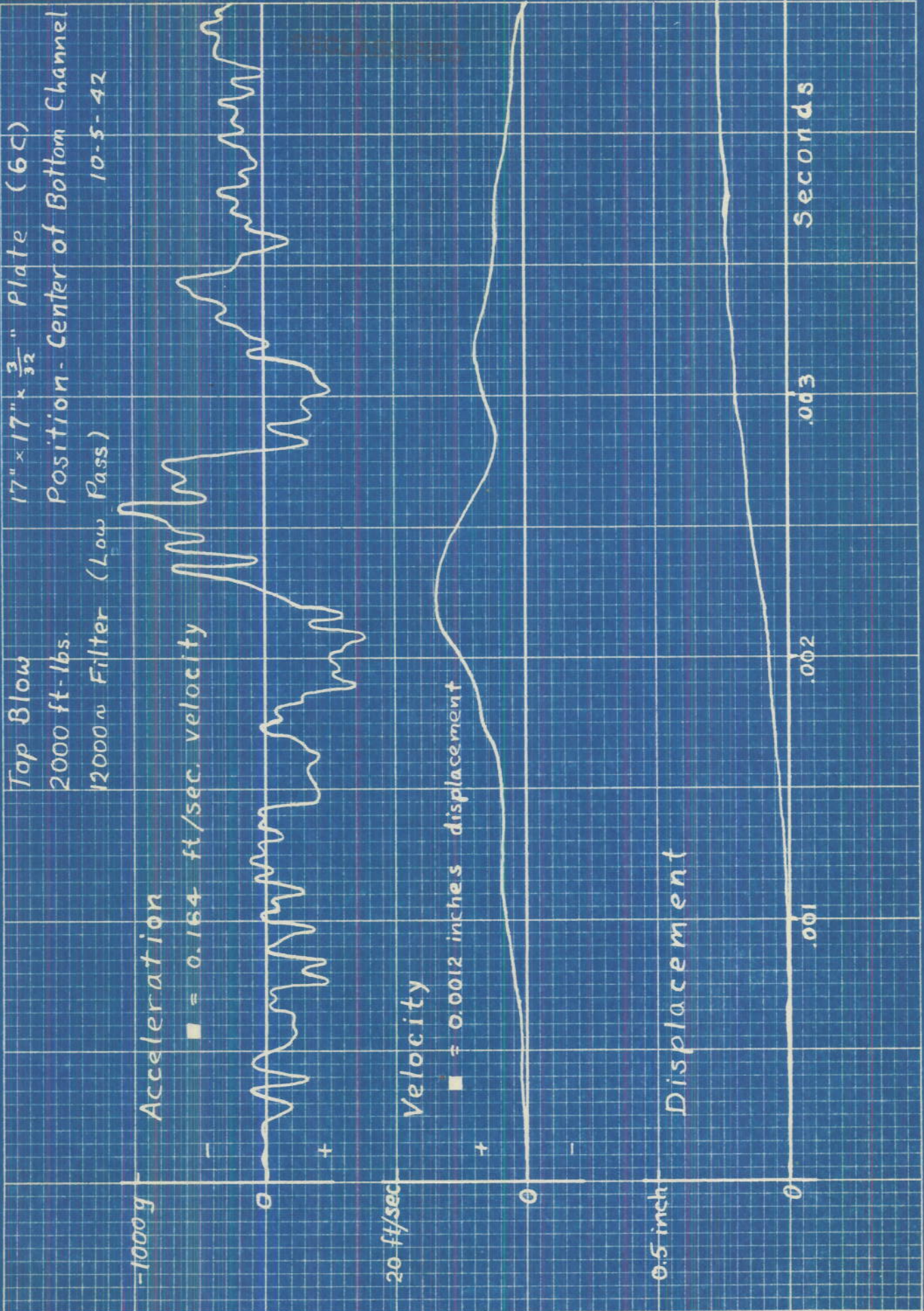
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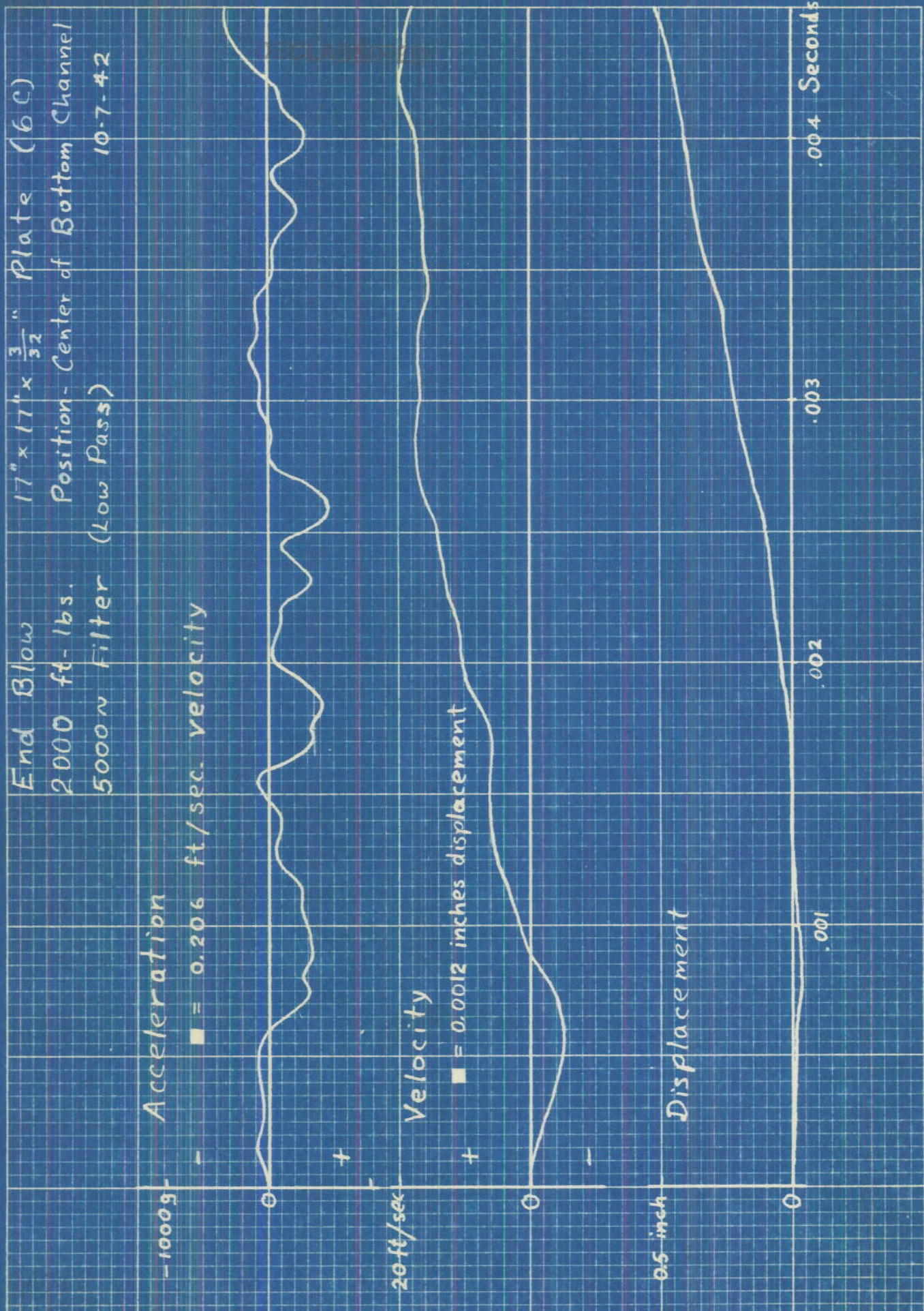
.001

.002

.003

Seconds







NO. 311150. 10 DIVISIONS PER INCH EACH WAY. 70 X 100 DIVISIONS. CODEX BOOK COMPANY, INC. WASHINGTON, MESSINGBOULETS.



Back Blow, 2000 ft - lbs.
Searchlight Mounting (4D)
Position on Pipe
5000 v Filter (Low Pass)
10-10-42

Acceleration

■ = 0.242 ft/sec.
velocity

-1000 g

20 ft/sec

■ = 0.0012 inches displacement

0.5 inch

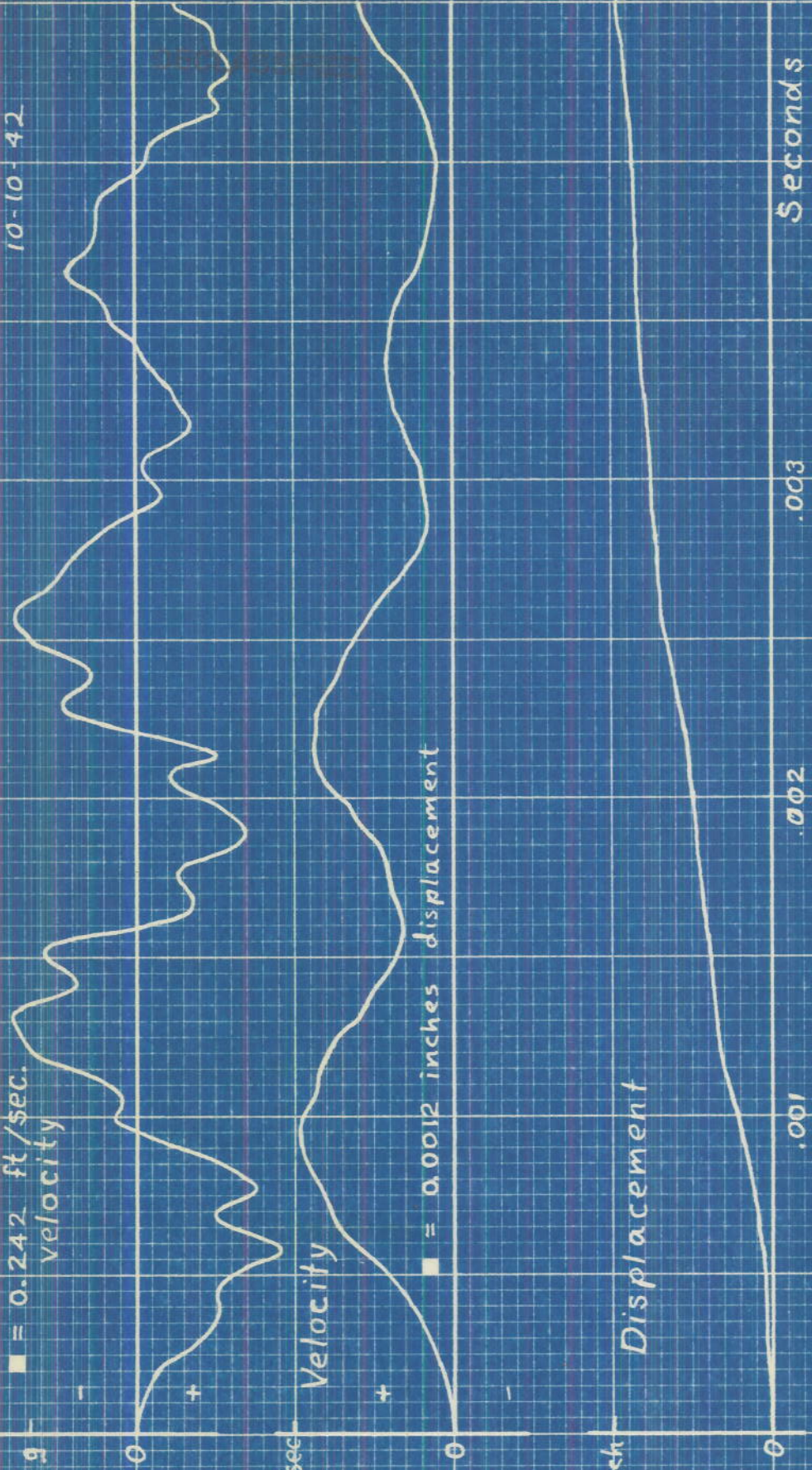
Displacement

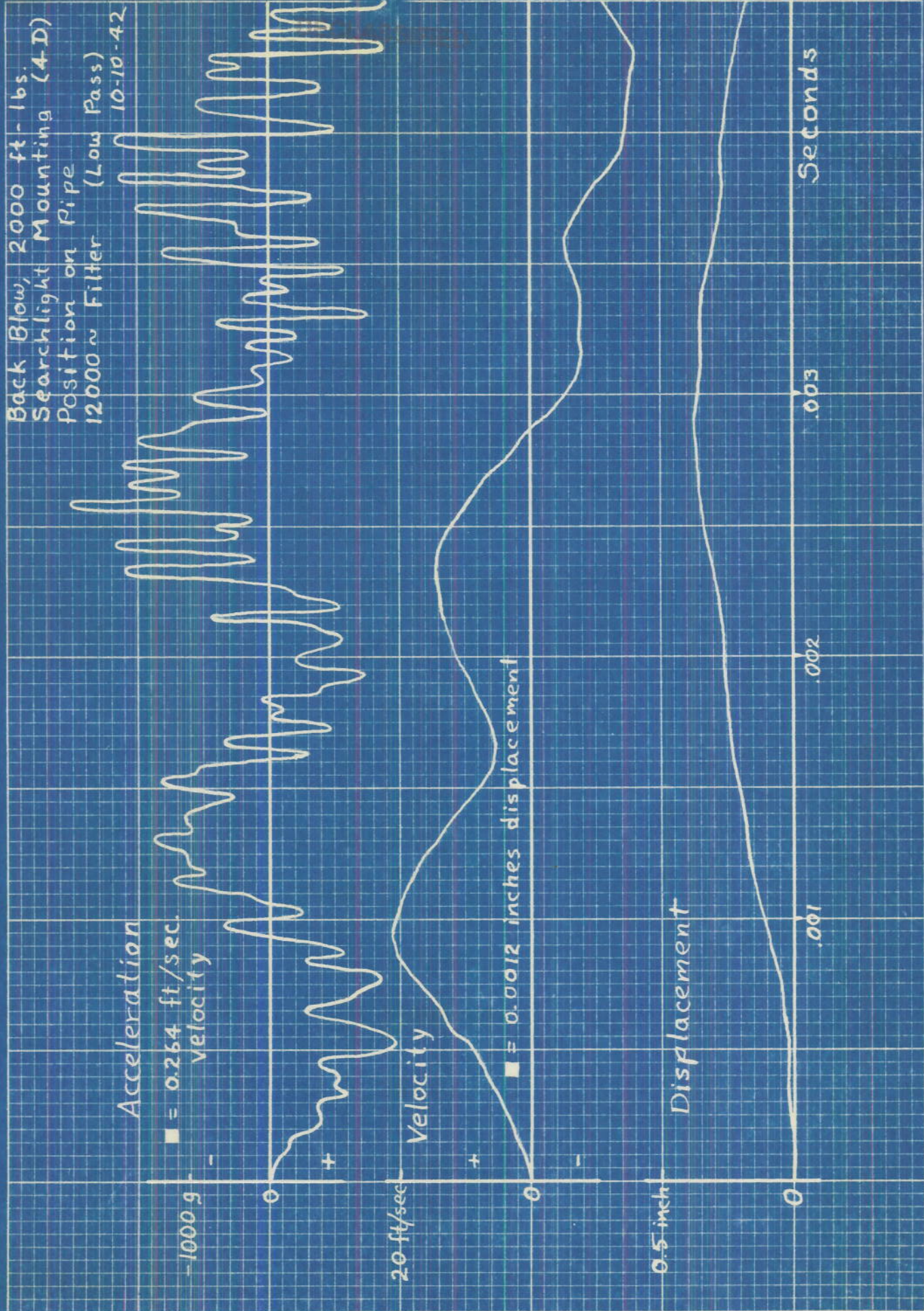
.001

.002

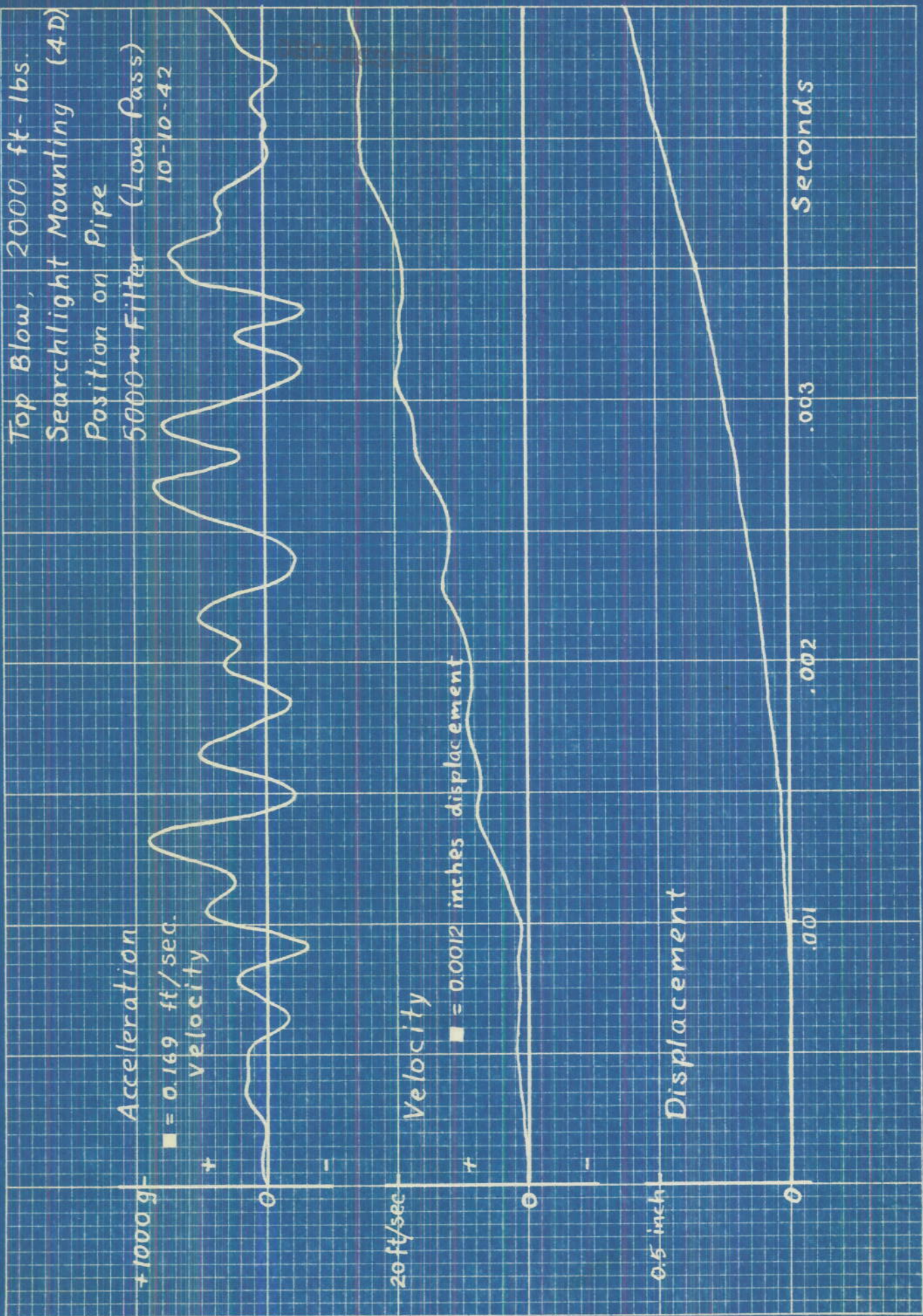
.003

Seconds





NO. 31,150. 10 DIVISIONS PER INCH BOTH VERTS. 70 X 100 DIVISIONS.



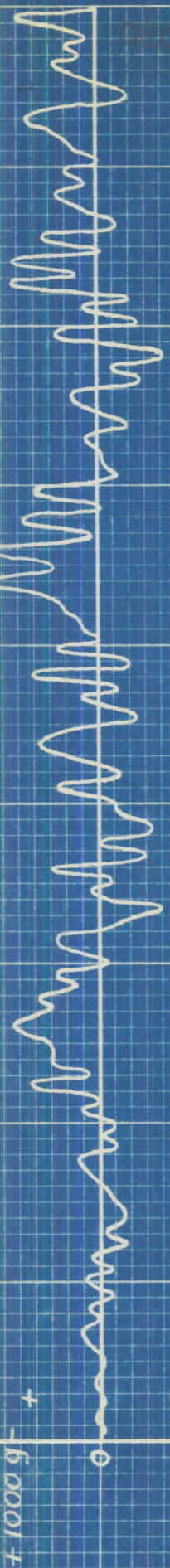


Top Blow, 2000 ft-lbs.
Searchlight Mounting (4D)
Position on Pipe

12000 ~ Filter (Low Pass)
10-10-42

Acceleration

■ = 0.288 ft/sec. velocity

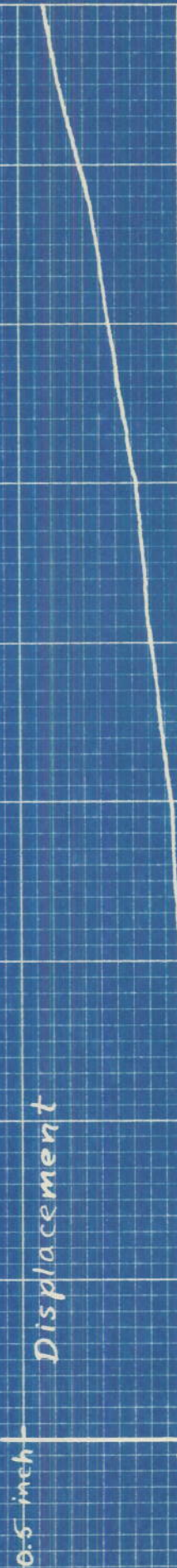


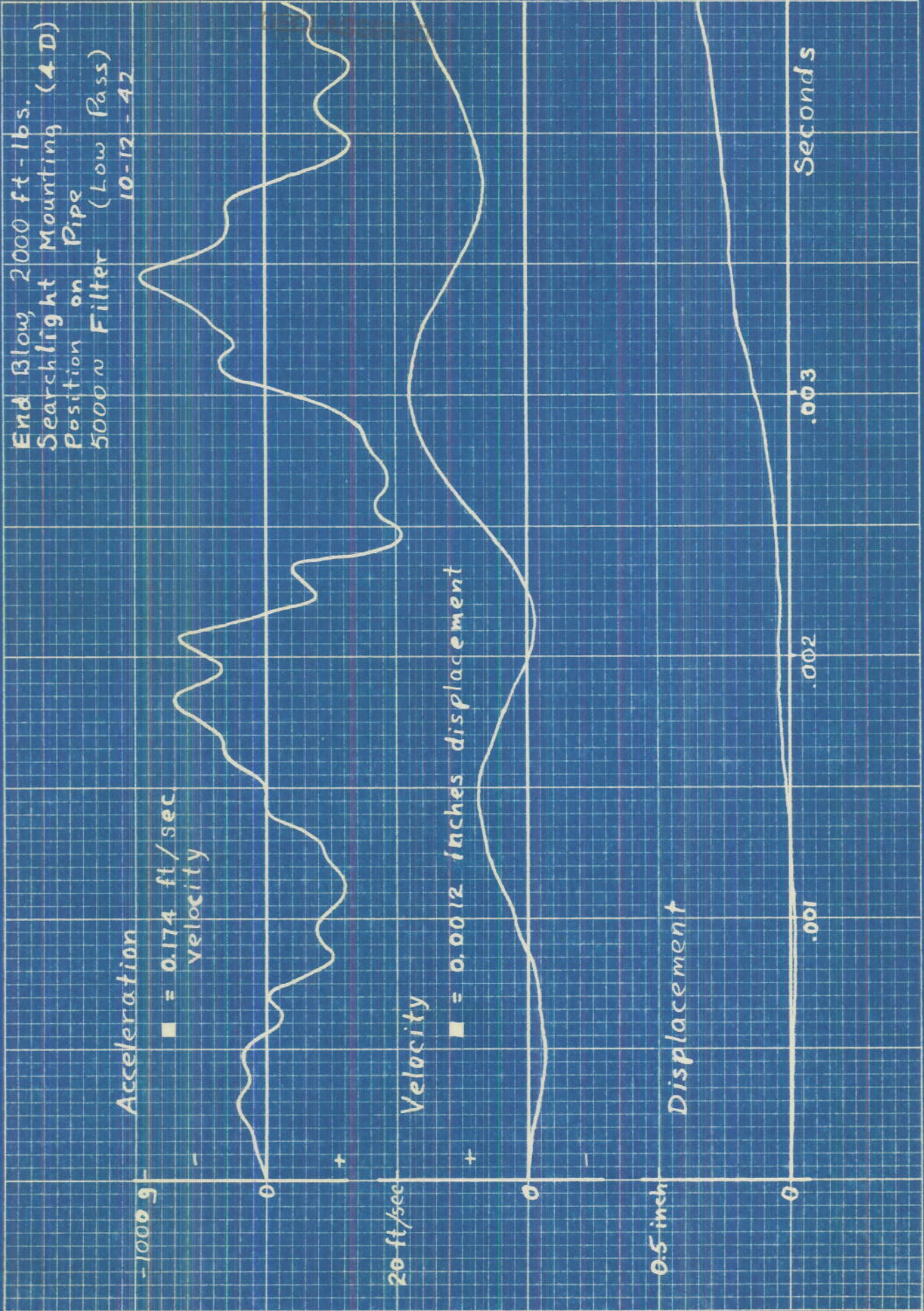
Velocity

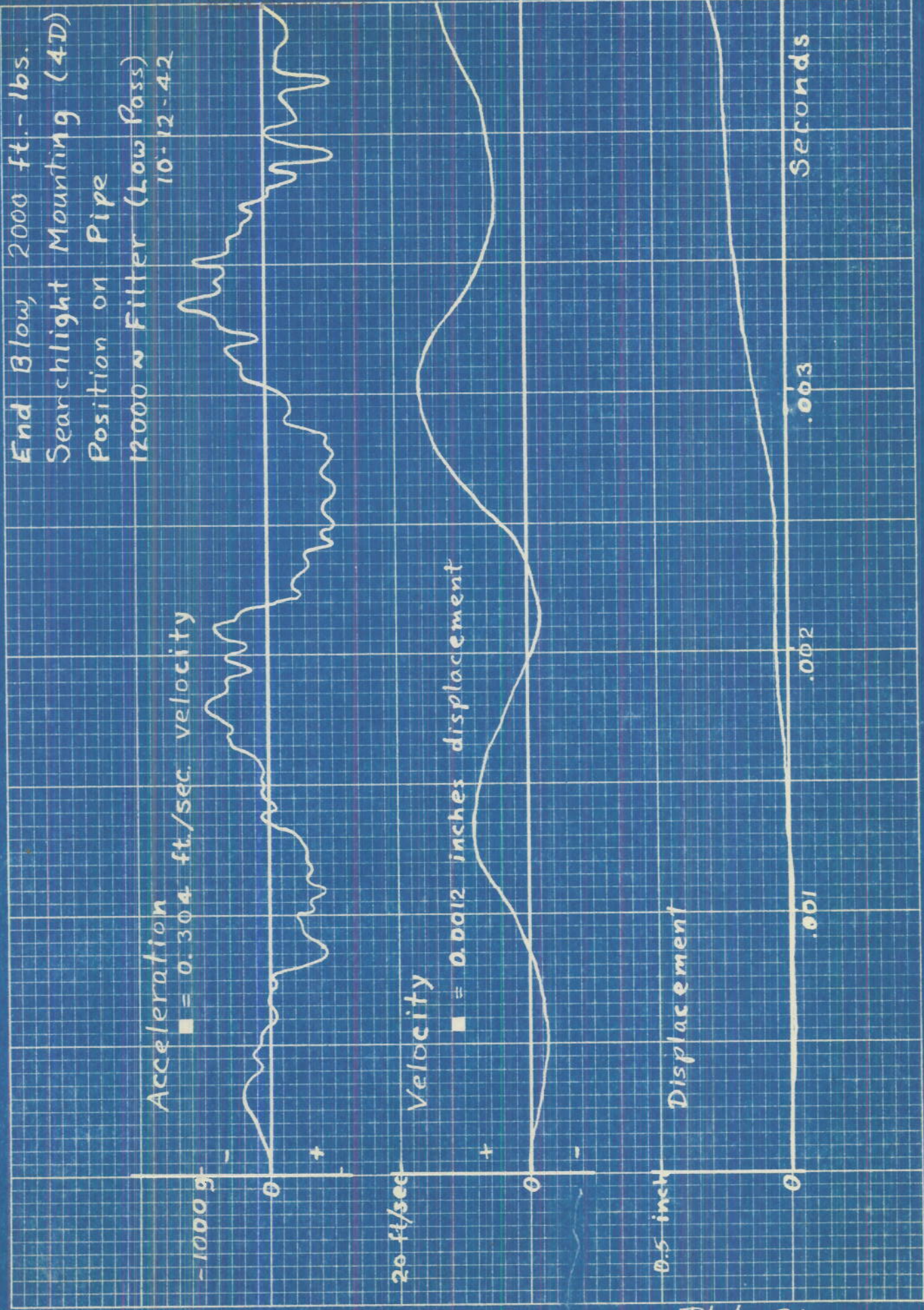
■ = 0.0012 inches displacement



Displacement







End Blow, 2000 ft.-lbs.
 Searchlight Mounting (4D)
 Position on Pipe
 12000 ~ Filter (Low Pass)
 10-12-42

Acceleration
 ■ = 0.304 ft./sec. velocity

Velocity
 ■ = 0.0012 inches displacement

-1000 g

20 ft/sec

0.5 inch

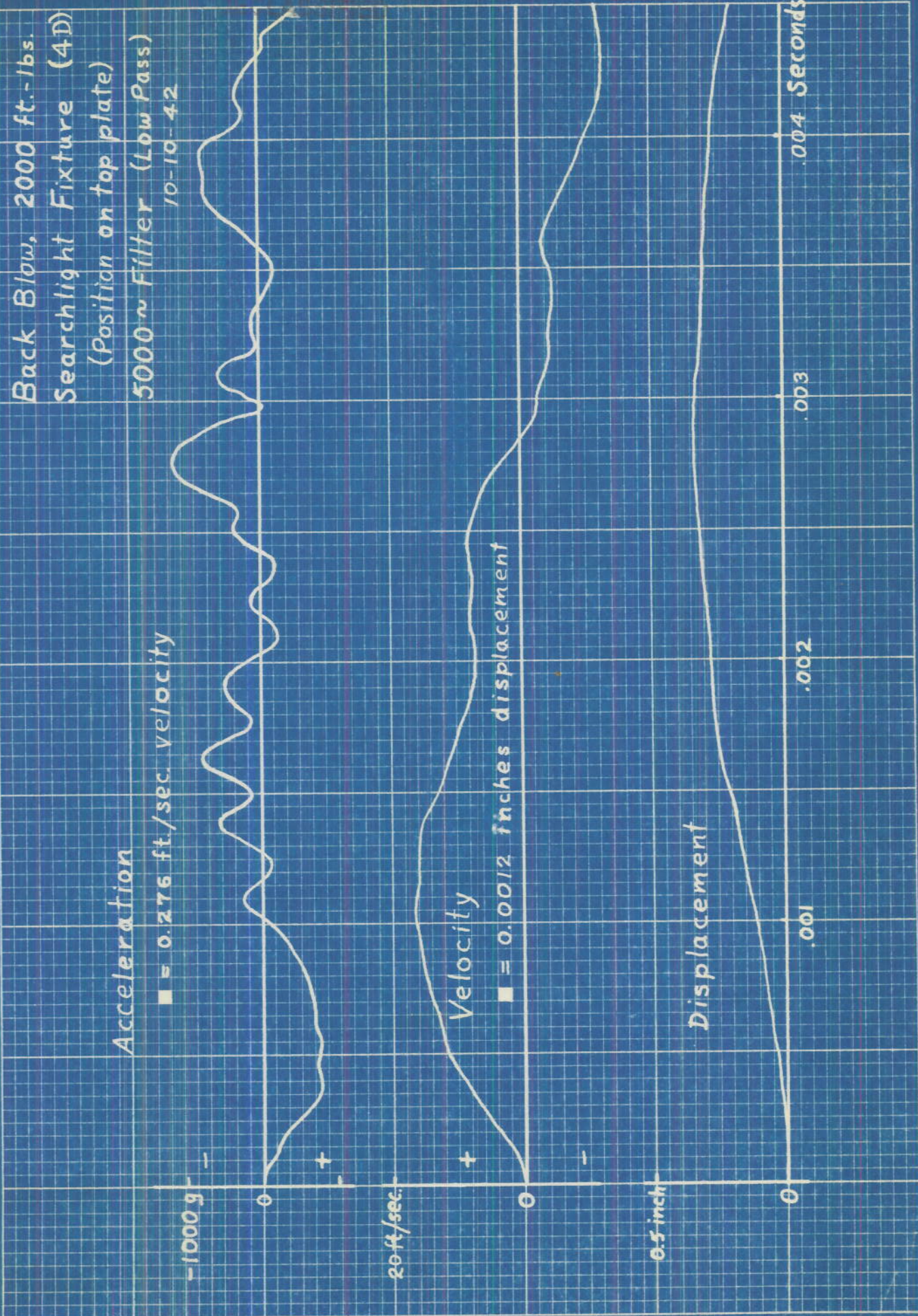
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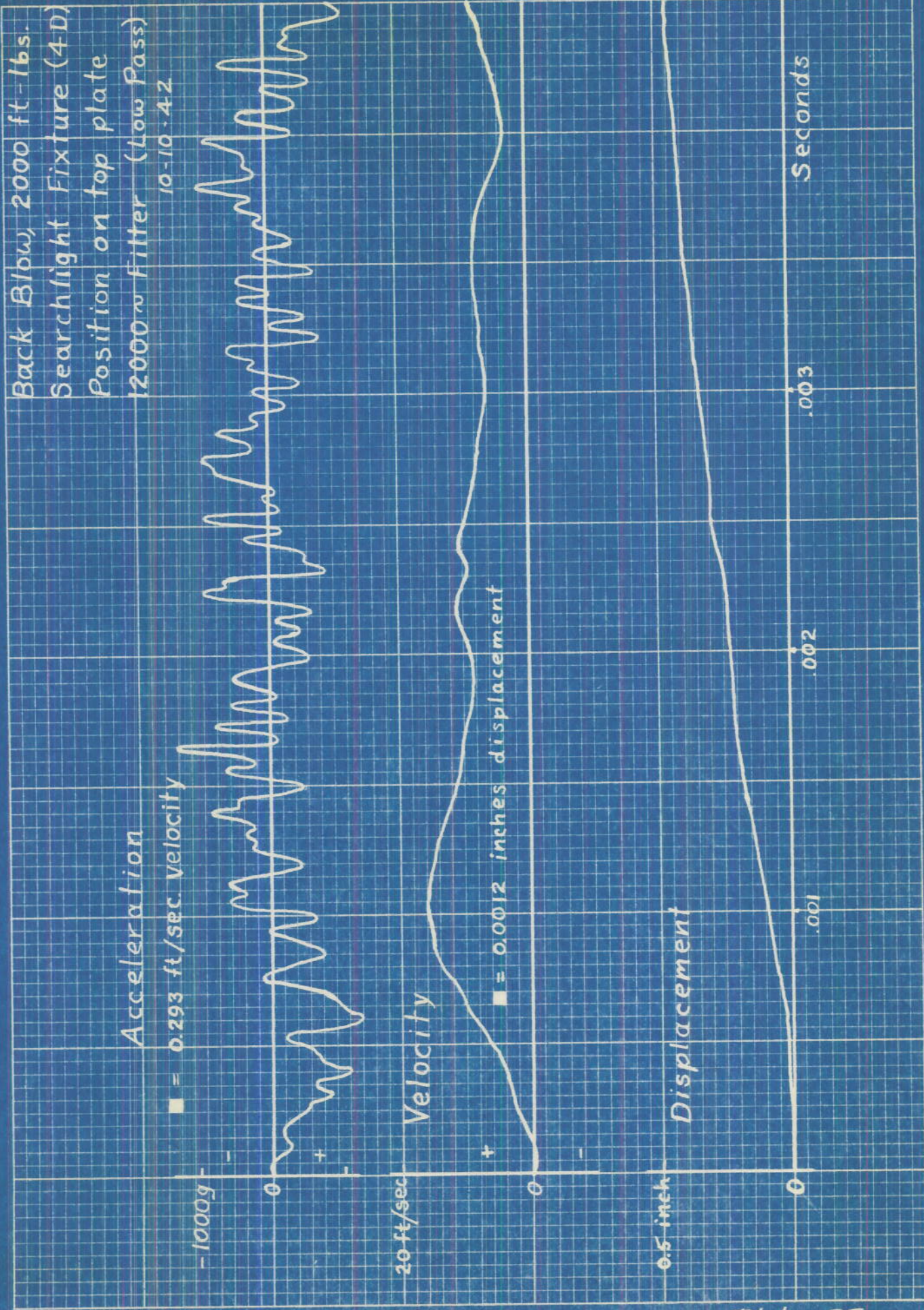
.001

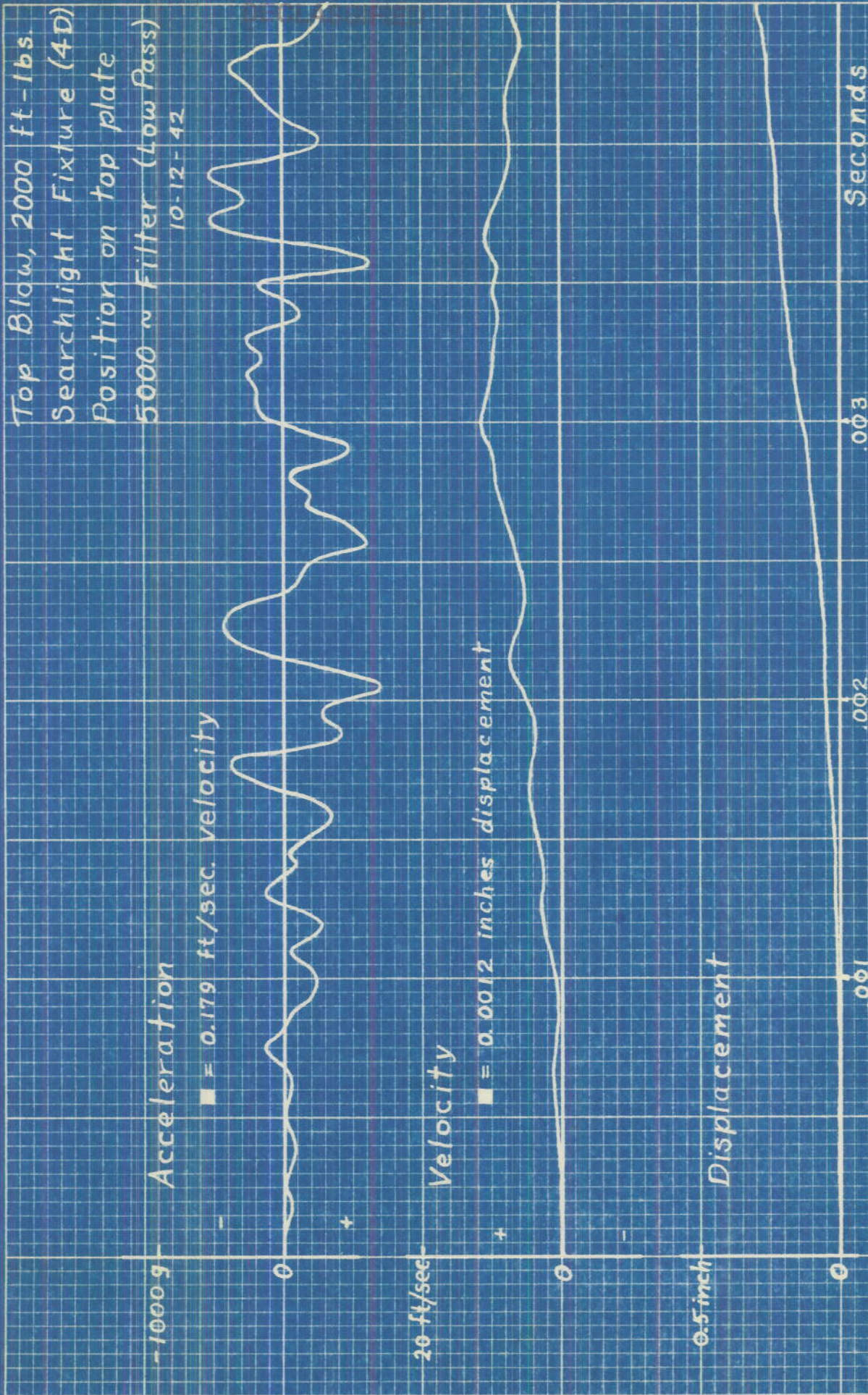
.002

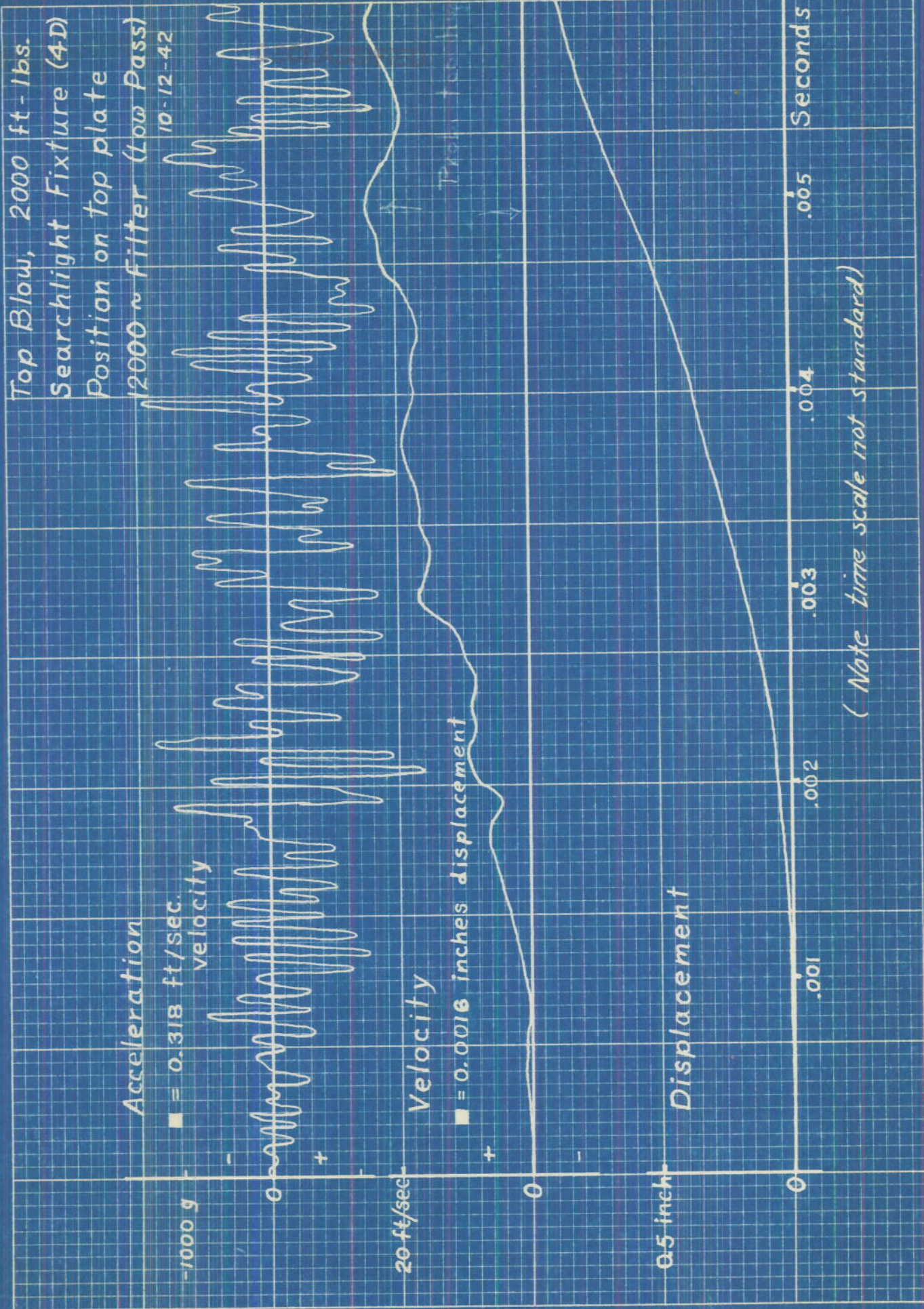
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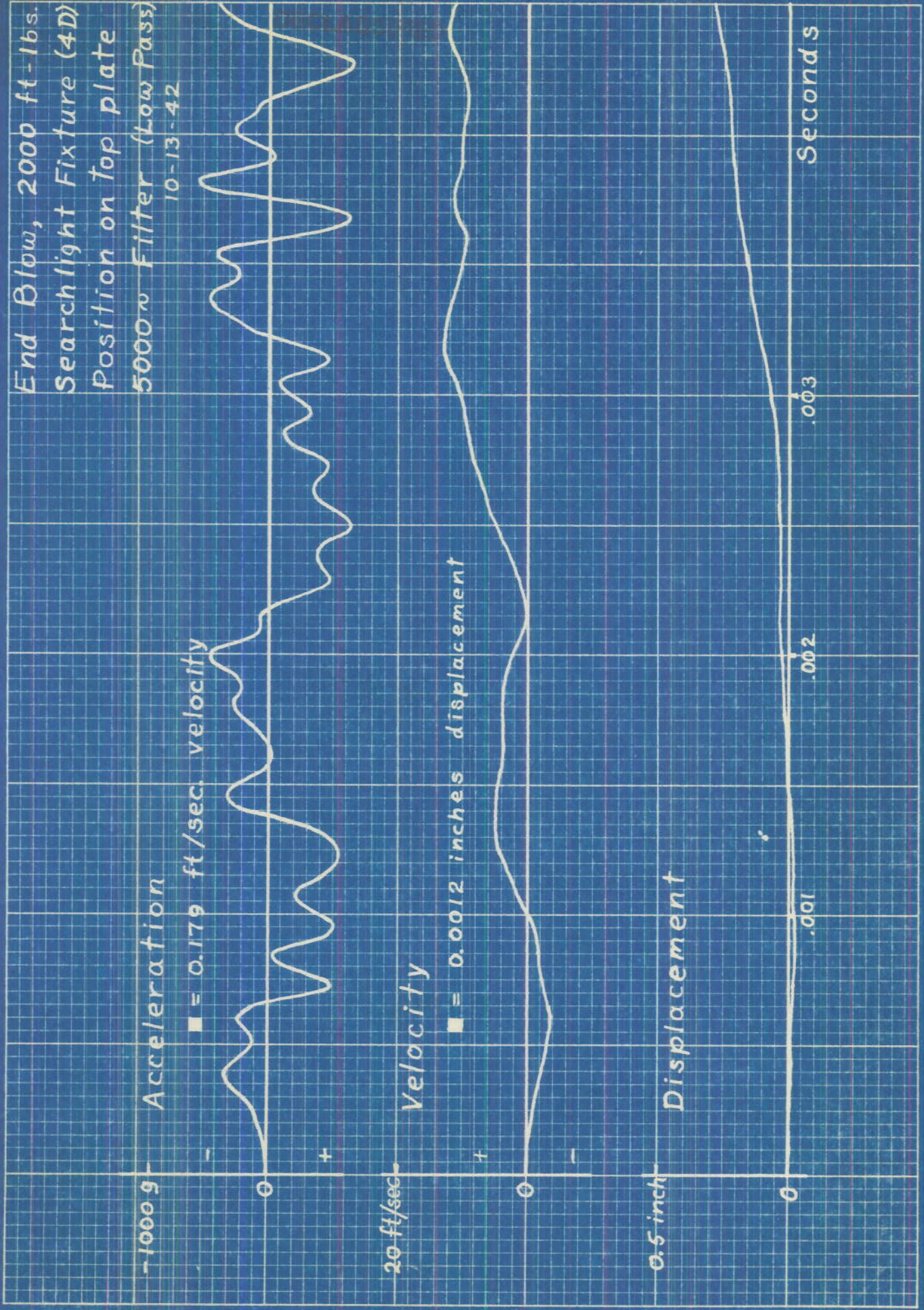
Seconds



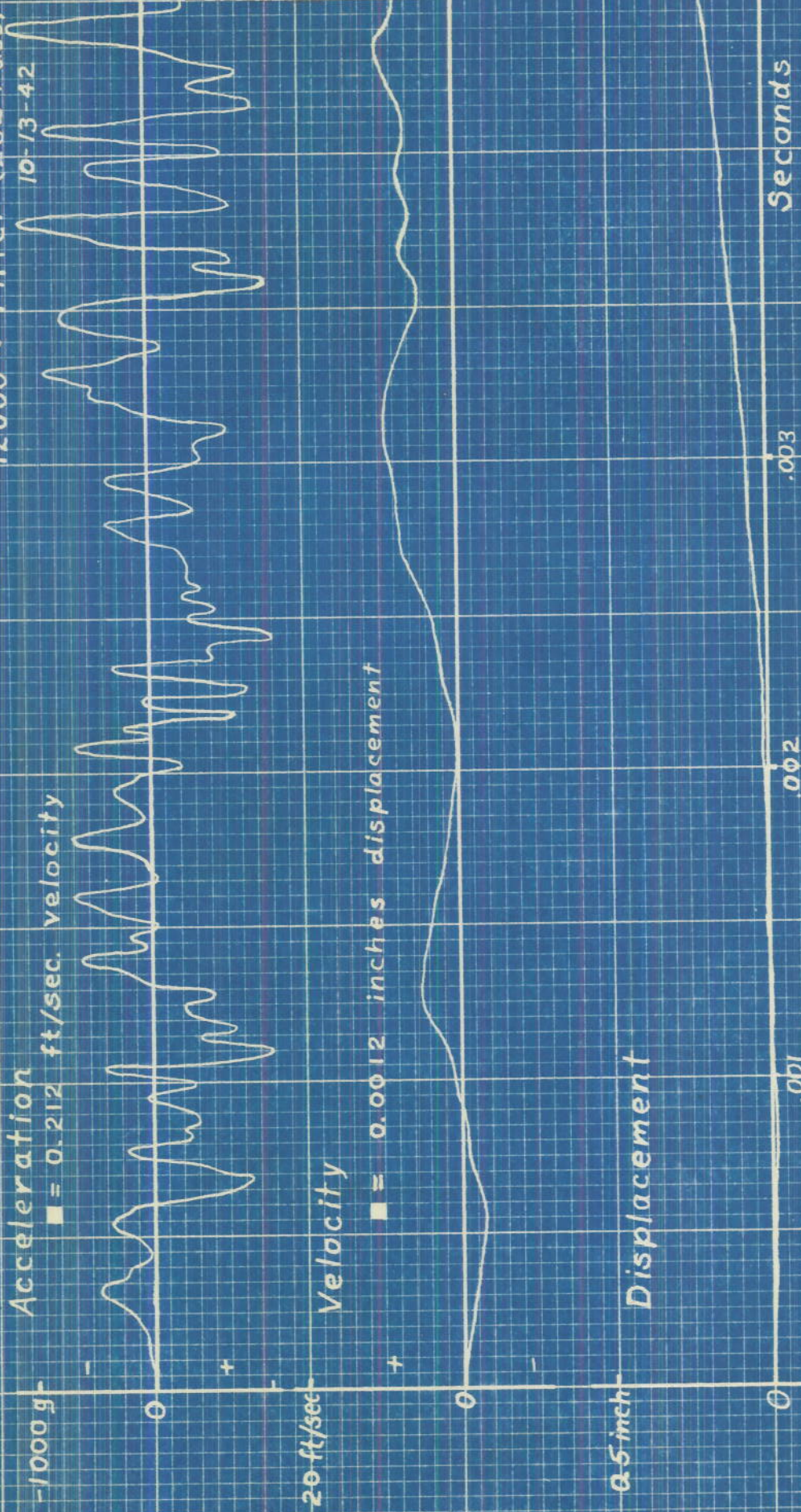






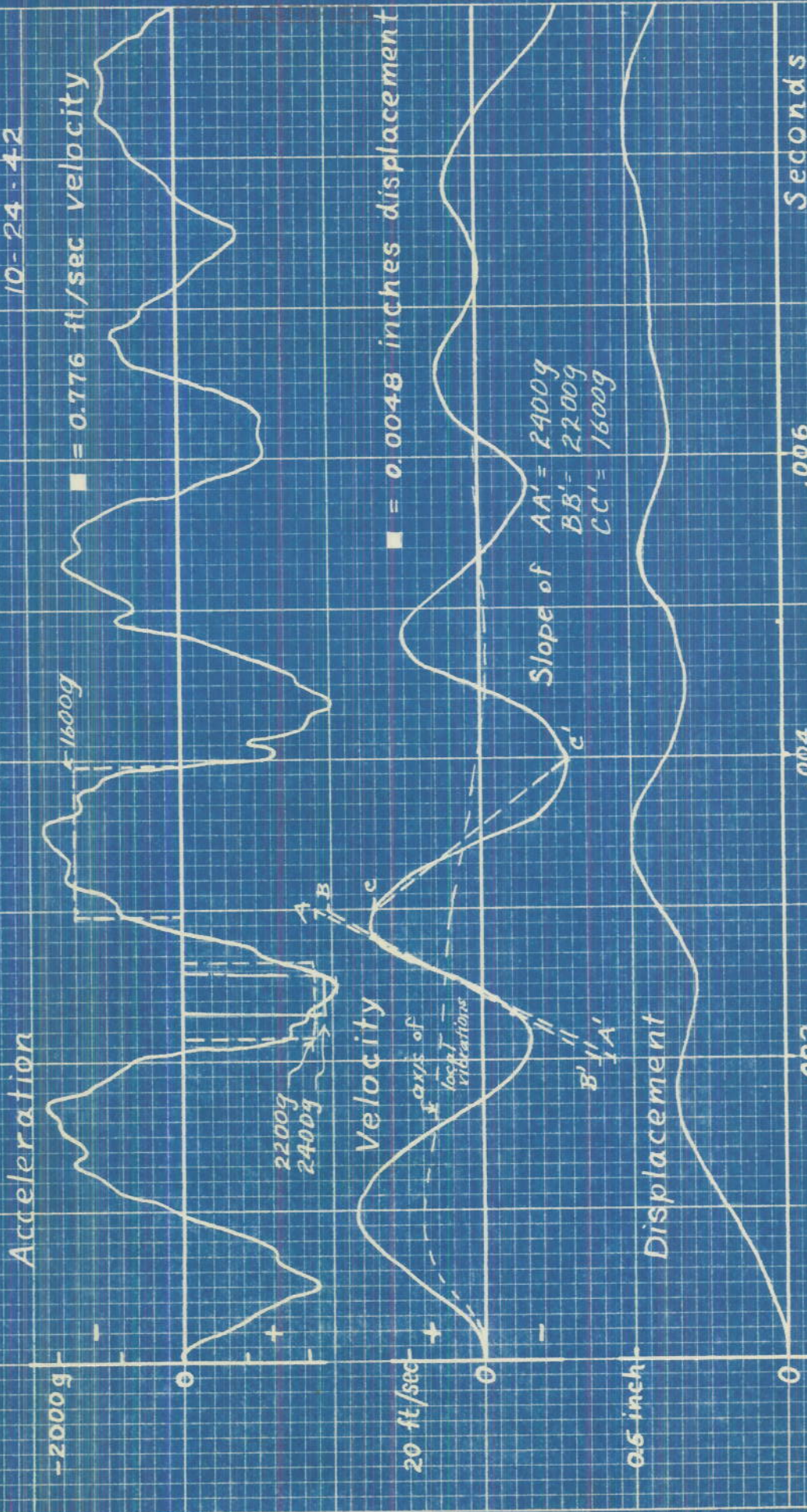


End Blow, 2000 ft-lbs.
Searchlight Fixture (4D)
Position on top plate
12000 ω Filter (Low Pass)





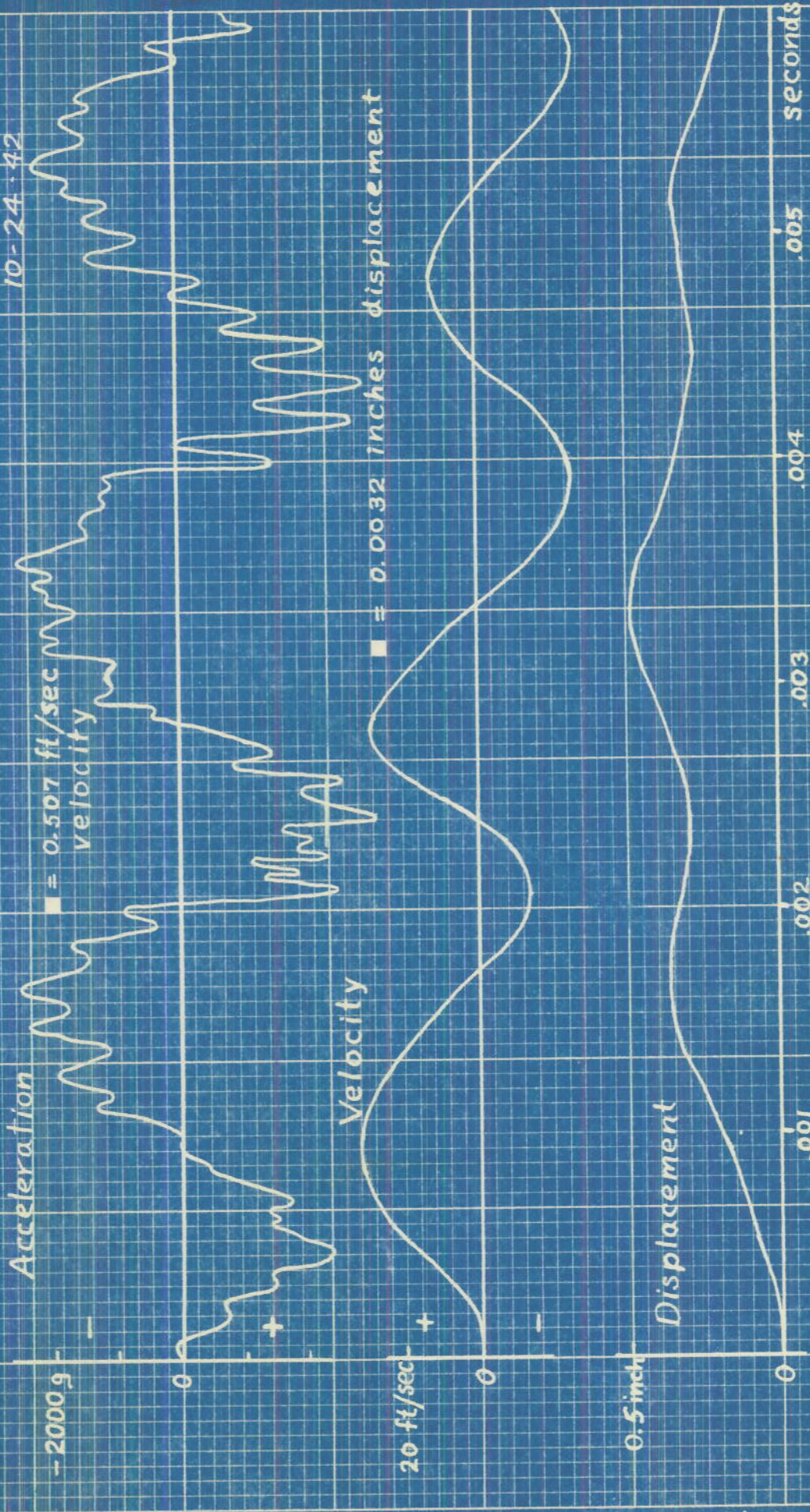
Back Blow, 2000 ft-lbs
Circuit Breaker Mounting (6B)
5000 ~ Filter (Low Pass)
10-24-42



(Note time Scale not standard)

Back Blow, 2000 ft-lbs
Circuit Breaker Mounting (6B)

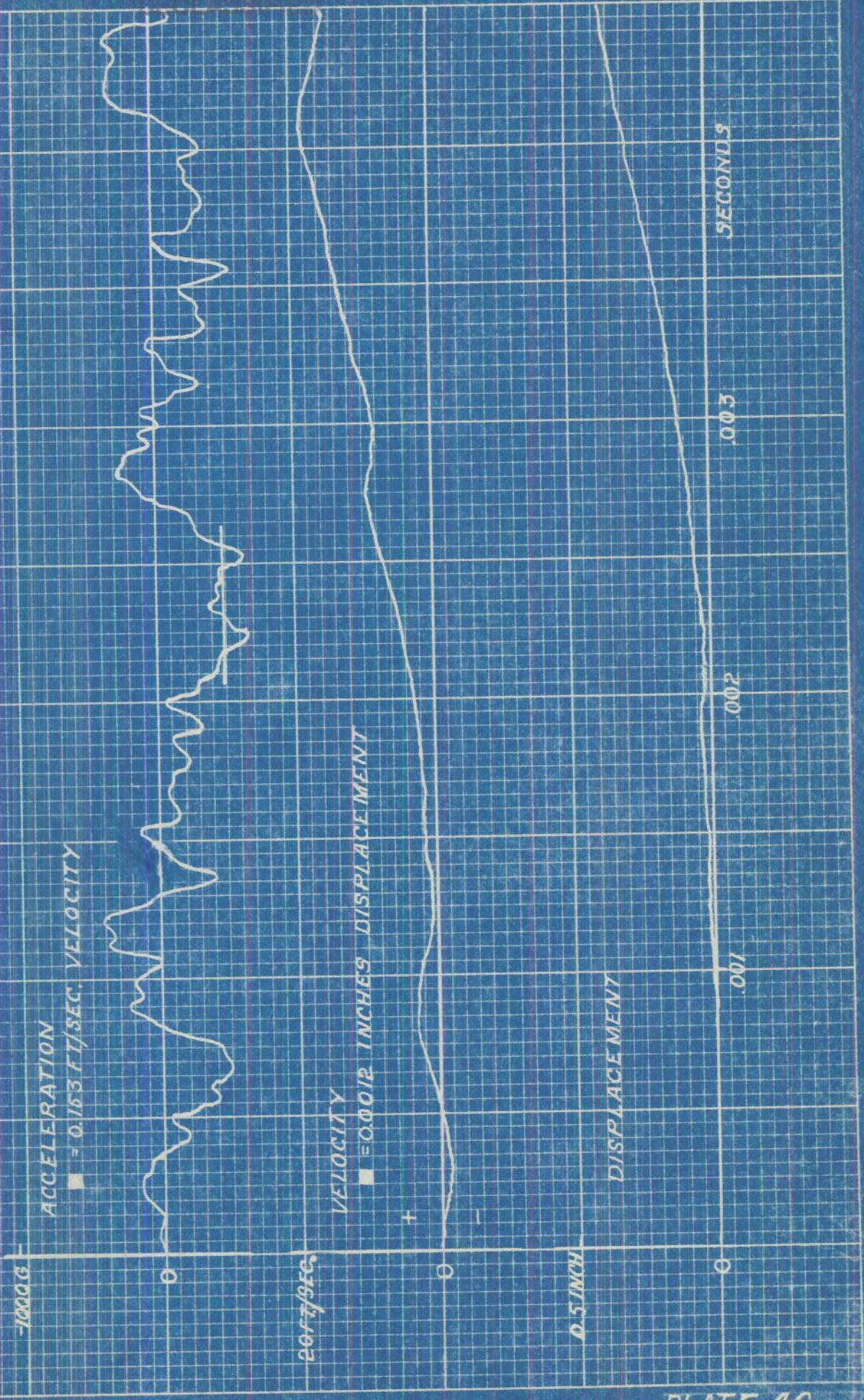
12000 ~ Filter (Low Pass)
10-24-42



(Note time scale not standard)



TOP BLOW, 2000 FT-LBS.
CIRCUIT BREAKER MOUNTING (6B)
12000 ~ FILTER (LOW PASS)
10-24-42



ACCELERATION
■ = 0.163 FT/SEC. VELOCITY

VELOCITY
■ = 0.0012 INCHES DISPLACEMENT

DISPLACEMENT

END BLOW, 2000 FT. LB.
CIRCUIT BREAKER MOUNTING (6B)
12000 ~ FILTER (LOW PASS)
10-26-42

